Issued June 30, 1913.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 165.

A. D. MELVIN, Chief of Bureau.

THE MANUFACTURE OF CHEESE OF THE CHEDDAR TYPE FROM PASTEURIZED MILK.

BY

J. L. SAMMIS, Ph. D.,

Associate Professor of Dairy Husbandry, College of Agriculture,
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., January 30, 1913.

Sir: I have the honor to transmit for publication as a bulletin of this bureau the accompanying manuscript entitled "The Manufacture of Cheese of the Cheddar Type from Pasteurized Milk," by Prof. J. L. Sammis, of the College of Agriculture, University of Wisconsin, and Mr. A. T. Bruhn, expert cheese maker in the Dairy Division of this bureau. The work herein described was conducted at Madison, Wis., in cooperation between the Dairy Division and the Wisconsin Agricultural Experiment Station.

The Dairy Division has been represented at Madison by L. D. Bushnell, Alfred Larson, and Miss Alice C. Evans, bacteriologists, in succession; S. K. Suzuki and E. F. Flint, chemists, and J. W. Moore, F. W. Laabs, and A. T. Bruhn, expert cheese makers, in succession, all of whom have assisted at various times in this work. The Wisconsin Station has been represented by Prof. Sammis, who from the beginning has had charge of the cooperative experiments in the manufacture of the Cheddar type of cheese from pasteurized milk.

The comparison of this cheese with that made from raw milk by the regular factory method has been systematically and thoroughly carried out under a variety of conditions by the use of duplicate vats of milk, one of these being pasteurized in each instance. During 1910 and 1911, especially in the latter year, the new process was perfected and a large quantity of the pasteurized cheese was made under commercial conditions and placed upon the open market. The results are fully described, also the process of making the cheese, and it is shown that the use of pasteurized milk is highly satisfactory and economical. As pathogenic bacteria have been found to survive for several months in cheese made from raw milk, the pasteurization of milk in making cheese is also desirable for the protection of the health of the consumer.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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INTRODUCTORY.

THE NEED FOR A NEW METHOD OF CHEESE MAKING.

Economy of time and labor and improved quality and uniformity of the cheese produced make the large cooperative factory more profitable to farmers than the small factory, provided they retain the control, if not the complete ownership, of it. There are two objections sometimes raised against the replacement of four or five small cheese factories in a neighborhood by one large, better-equipped, better-manned, and more economical cheese factory, namely: First, that by present factory methods cheese makers could not make as good cheese from milk gathered over a large territory, because it would be longer on the road to the factory and therefore would not be so fresh as otherwise; second, farmers object to hauling milk a great distance, even to a good cheese factory.

The only way to get a large, first-class cheese factory located within a short distance of a sufficient milk supply is to centralize the latter—that is, to keep as many of the best cows on every farm as the land will support. Until this is done there will be many factories which must draw milk from a large area. Some modification of present cheese-factory methods is needed by which milk from a large territory can be successfully handled.

The great amount of inferior cheese on the market and the lack of uniformity which characterizes the product of the present cheese factory of average size is due primarily to the variable quality of the milk supply from different farms, especially as to the presence of dirt and bacteria, which produce faulty flavors and textures in great variety, and to the variable ripeness or acidity of the milk received from day to day, depending upon the care given to it on the farm, its age, etc.

The immediate effect of these conditions is that cheese makers in their effort to produce cheese of uniform quality from milk of variable quality must necessarily use methods which vary from day to day and from factory to factory. Under this system each vat of milk must be watched carefully at every stage of its manufacture, and the

cheese-making process must be hastened, or delayed, or modified every day, according to the cheese makers' judgment. The yield of cheese also varies from day to day, depending upon the quality of the milk and the method used in handling it.

The ideal conditions for cheese making require an absolutely clean and perfect milk supply, and this can not be realized until methods of milk production on the farm are vastly improved. In the meantime a process for treating milk daily at the factory so as to bring it into practically uniform condition for cheese making purposes is needed. Such a process should include means for stopping the ripening and the growth of harmful bacteria, etc., in the milk as soon as it is received at the factory, in order that it may be ripened with a clean starter, in a uniform manner, daily. The process should be applicable to milk of any degree of ripeness which can properly be accepted as fit for cheese making from a sanitary standpoint. When milk is thus brought by a preliminary treatment into uniform condition at the factory, both as to acidity and as to bacterial content, the present variable and irregular methods of making cheese could probably be replaced by a routine process, operated upon a fixed time schedule without variation from day to day. As a result, it is to be expected that the uniformity, quality, and yield of cheese would be much improved as compared with that obtained by the older methods. In many other lines of manufacture in recent years preliminary processes have been devised for bringing raw materials into uniform condition before they enter the manufacturing process, and improved products, increased economies, and larger output and profits have resulted. It is desirable that the same general methods of improvement which have been used with success in other lines be applied also to the cheese-making industry.

FAULTS TO BE CORRECTED IN MILK FOR CHEESE MAKING.

The defects most commonly met with in milk, which must be corrected by such a preparatory process as that contemplated, are of bacterial origin. A variable content of lactic-acid bacteria causes milk when received at the factory to exhibit different degrees of acidity and also causes the subsequent development of acid in the milk and curd, while in the vat, to go on at varying rates. On account of the important influence which acidity has upon the rate at which whey is expelled from curd, as pointed out in a previous bulletin,[1] it may well be said that this is the leading controlling factor in the manufacture of American Cheddar cheese. Therefore it is of prime importance to secure milk of uniform acidity with which to

[1] Sammis, J. L., Suzuki, S. K., and Laabs, F. W. Factors controlling the moisture content of cheese curds. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 122. Washington, 1910. See p. 29.

begin cheese making, and also to provide for subsequent acid development at a practically fixed rate every day in order to avoid the present troubles due to irregular acid formation.

Those bacteria which produce gas or tainted, unclean flavors are all too common in milk, and are the cause of much trouble in the cheese factory. Bacteria which produce diseases such as tuberculosis, typhoid fever, diphtheria, dysentery, etc., have often been found in milk, although it is difficult to prove that any person ever contracted these diseases from eating cheese. These and other bacterial infections of raw cream and milk for city trade are usually combated by pasteurization; this is true, likewise, in butter making, and with skim milk when used for feeding stock. It seems reasonable, therefore, that any process, such as pasteurization, which will kill the acid, taint, gas, and disease-producing organisms in milk would also improve the quality of the cheese produced therefrom.

THE NECESSITY FOR THE PASTEURIZATION OF MILK FOR CHEESE MAKING.

In view of the possible presence of tubercle bacilli in market cheese, Mohler[1] in 1908 recommended the "pasteurization of the milk in order to make the cheese perfectly safe." Mohler, Washburn, and Doane[2] prepared and studied cheese from milk to which cultures of bacillus tuberculosis had been added. They inoculated guinea pigs with such cheese at various periods of time after its manufacture and found that—

> Advancing cases of generalized tuberculosis were developed (in guinea pigs) by means of inoculation of cheese 220 days old, and that slight tubercular lesions were caused by the injection of an emulsion of cheese when 261 days old."

They add:

> If it is possible to use pasteurized milk in the manufacture of cheese without injuring the product a simple solution of the problem is offered to the cheese manufacturer in the process known as pasteurization.

These authors also give a brief résumé of previous work on this subject in Europe and America.

It is evident that the bacillus of tuberculosis not only retains its life but also its virulence in cheese for a considerable period of time, and that cheese made from raw, unpasteurized milk should therefore be considered as a possible carrier of tubercle bacilli.

There is a strong tendency at the present time to cure American cheese more rapidly than in the past, so that it commonly reaches

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[1] Mohler, John R. Conditions and diseases of the cow injuriously affecting the milk. U. S. Treasury Department, Public Health and Marine-Hospital Service, Hygienic Laboratory, Bulletin 41. Washington, 1908. See p. 495.

[2] Mohler, John R., Washburn, Henry J., and Doane, C. F. The viability of tubercle bacilli in cheese, Twenty-sixth Annual Report of the Bureau of Animal Industry, U. S. Department of Agriculture (1909), pp. 187–191. Washington, 1911.

the consumer at a less age than four months. It has also been shown [1] that practically all—95 to 98 per cent—of the bacteria present in milk are retained in the cheese. These facts serve to emphasize the desirability of pasteurizing milk for cheese making.

An ordinance passed by the common council of the city of Chicago July 13, 1908, contemplated the pasteurization of milk used for cheese making, although at that date no practical methods for making American cheese from pasteurized milk had been published. The ordinance was as follows:

Cheese Be it ordained by the city council of the city of Chicago, * * *

SECTION 2. It shall be unlawful to sell any such cheese in the city of Chicago unless there be stamped on the package in plainly legible letters of not less than one-eighth inch type: "Made of milk (or cream) from cows free from tuberculosis as shown by tuberculin test," or "made from milk (or cream) pasteurized according to the rules and regulations of the department of health of the city of Chicago * * *."

SEC. 4. This ordinance shall be in full force and effect from and after January 1, 1909.

AMOUNT OF HEAT NECESSARY TO DESTROY VARIOUS BACTERIA.

The question as to what temperature of pasteurization will kill disease-producing bacteria in milk is of interest to the consumer and all connected with the business.

The thermal death point of various pathogenic organisms is already well known. Rosenau states as a result of his work and that of others that "milk heated to 60° C. (140° F.) and maintained at that temperature for two minutes will kill the typhoid bacillus." The great majority of these organisms are killed by the time the temperature reaches 1 or 2 degrees below the point named and few survive to 140° F.

The diphtheria bacillus succumbs at comparatively low temperatures. Oftentimes it fails to grow after heating to 55° C. (131° F.). Some occasionally survive until milk reaches 60° C. (140° F.). The cholera vibrio is similar to the diphtheria bacillus so far as its thermal death point is concerned. The dysentery bacillus is somewhat more resistant to heat than the typhoid bacillus. It sometimes withstands heating at 60° C. (140° F.) for five minutes. All, however, are killed when held at this temperature for ten minutes.[2]

In 1904 Russell and Hastings [3] found that the tubercle bacillus is killed by heating at 71° C. (160° F.) for one minute.

From the foregoing it is clear that pasteurization at 71° C. (160° F.) for one minute, and in most cases for a shorter period, is effective in

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[1] Sammis, J. L., Suzuki, S. K., and Laabs, F. W. Factors controlling the moisture content of cheese curds. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 122. Washington, 1910. See p. 29.

[2] Rosenau, Milton J. The thermal death points of pathogenic microorganisms in milk. U. S. Treasury Department, Public Health and Marine-Hospital Service, Hygienic Laboratory, Bulletin 56, pp. 683–686. Washington, 1909.

[3] Russell, H. L., and Hastings, E. G. Effect of short periods of exposure to heat on tubercle bacilli in milk. Wisconsin Agricultural Experiment Station, Twenty-first Annual Report (1904), pp. 178–192. Madison, 1904. See p. 185.

destroying pathogenic bacteria in milk and preventing their entrance into cheese.

Babcock and Russell,[1] from their experiments upon the thermal destruction of galactase, state that "heating the enzym solutions for 10 minutes at 76° C. (169° F.) suffices to destroy the digestive ferment galactase, and even at 71° C. (160° F.), for the same exposure, its action was materially reduced." It seems likely, therefore, that an exposure to 160° F. for 1 minute or less in the continuous pasteurizer would not greatly weaken the action of this enzym in milk for cheese-making purposes.[2]

Much less attention has been paid by bacteriologists to the thermal death point of those bacteria in milk which produce gas and tainted flavors in cheese. Moore and Ward [3] have described a gas-producing bacillus isolated from milk and from gassy cheese which "is destroyed in freshly inoculated small tubes of bouillon when exposed to a temperature of 60° C. (140° F.) for 10 minutes in a closed water bath."

It is to be hoped that in the future investigators will determine also the minimum temperature required to kill various species of milk bacteria with an exposure of 1 minute or less as in the continuous pasteurizer.

PREVIOUS ATTEMPTS TO MAKE CHEESE FROM PASTEURIZED MILK.

The possibility of making American cheese from pasteurized milk has been studied at several experiment stations and elsewhere. The two difficulties met with are:

First, the fact, long known, that heated milk coagulates slowly with rennet, giving a loose, spongy curd which is not suitable for cheese making because it is too fragile to be handled.

Second, pasteurization causes curd to expel whey more slowly than otherwise.

In order to restore the coagulability with rennet to pasteurized milk, Klein and Kirsten [4] in 1898 added calcium chlorid and a bacterial starter and were able to obtain fairly good limburger and other soft cheeses. They used for 100 kilograms of skim milk 100 to 125 cubic centimeters of a solution containing in 100 c. c. 40 grams of calcium chlorid, corresponding to 20 grams calcium oxid.

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[1] Babcock, S. M., Russell, H. L., and Vivian, Alfred. Properties of galactase: A digestive ferment of milk. Wisconsin Agricultural Experiment Station, Fifteenth Annual Report (1898), pp. 77–86. Madison, 1898. See p. 82.

[2] Kastle, Joseph H., and Roberts, Norman. The chemistry of milk. U. S. Treasury Department, Public Health and Marine-Hospital Service, Hygienic Laboratory, Bulletin 56, pp. 315–417. Washington, 1909.

[3] Moore, V. A., and Ward, A. R. An inquiry concerning the source of gas and taint producing bacteria in cheese curd. New York (Cornell) Agricultural Experiment Station, Bulletin 158. Ithaca, 1899. See p. 236.

[4] Klein and Kirsten, A. Versuche, betreffend die Wiederherstellung der Verkäsumgsfähigkeit erhitzter Milch durch Chlorcalciumzusatz. Milch-Zeitung, vol. 27, no. 50, pp. 785–787, Dec. 10; no. 51, pp. 803–805, Dec. 17. Leipsic, 1898. See also Fleischmann, W. Lehrbuch der Milchwirtschaft. 4th edition. Leipsic, 1908. See pp. 304, 305.

In Denmark a kind of cheese is made from pasteurized skim milk to which about 10 per cent of buttermilk is added so as to bring the acidity up to about 0.21 per cent just before adding rennet.[1]

In 1907 Dean [2] stated as a result of experiments in the use of calcium chlorid with pasteurized milk for cheese making "the coagulum was of a soft, weak nature and the cheese tended to be soft and porous." He also added 1½ to 3 per cent of bacterial starters to milk pasteurized at 180° F. and ripened some time before adding rennet. The rennet coagulated the milk, but the curd was weak in body. He noted an increased yield of cheese, but the cheese tended to be open and weak in body and texture. He adds:

> On the whole the results are not very satisfactory and we shall require more light on the subject of making pasteurized milk cheese before we could recommend the method to Canadian cheese makers.

In 1910 C. A. Publow [3] mentioned briefly some experiments in making cheese from pasteurized milk, adding to each 100 pounds of milk 2 cubic centimeters of a 25 per cent solution of calcium chlorid and 2 or 3 pounds of bacterial starter. The details of the method and the opinions of cheese judges other than the author respecting the product are not published. At this station in previous years efforts have been made to obtain good American cheese from pasteurized milk with the aid of calcium chlorid, but without success.

DIFFICULTIES MET IN MAKING CHEESE FROM PASTEURIZED MILK.

Pasteurization of milk prevents or greatly delays subsequent coagulation with rennet. The curd from such milk when finally cut into cubes expels moisture with much greater difficulty than a raw-milk curd, probably because of some chemical change produced in the casein by the heat of pasteurization. Rapid acid formation by bacterial action which occurs in raw milk and raw-milk curds does not occur in the pasteurized material. The presence of a moderate amount of lactic acid in raw-milk curds greatly hastens the separation of whey from the curd, and the lack of acid development in pasteurized-milk curds is another condition favoring the retention of excessive moisture in the curd and cheese.

The addition of calcium chlorid to milk which has been pasteurized is known to restore in a measure the coagulability of the milk with rennet, but we have observed, as Publow [4] points out, that, although coagulation begins in about five minutes, "the curd does not become firm enough for cutting in the usual time and should not be cut before it is firm." Although the addition of calcium chlorid restores

[1] Decker, John W. Cheese making. 5th edition. Madison, Wis., 1909. See p. 194.

[2] Dean, H. H. Experiments in cheese making. Ontario Agricultural College, Thirty-third Annual Report (1907). Toronto, 1908. See p. 120.

[3] Publow, Charles A. Fancy cheese in America. Chicago, 1910. See p. 20.

[4] Loc. cit. See p. 21.

the coagulability with rennet, it does not correct the acidity and the other difficulties mentioned above as being caused by pasteurization. The lack of acidity in such curd might be supplied by adding starter to the pasteurized milk and ripening for several hours before starting the cheese making, but the resulting loss of time would prohibit this practice in factories. Where both starter and calcium chlorid are added to milk after pasteurization, as suggested by Publow, and the cheese-making process is begun at once without waiting for ripening, the daily variations in natural acidity of the milk used produce corresponding variations in the moisture content of the cheese which affect its quality. (See Table 1.)

What is needed in place of calcium chlorid for addition to pasteurized milk is something which will not only restore the coagulability with rennet, but which will also bring up the acidity without delay to a sufficiently high percentage to induce reasonably rapid and complete separation of whey from curd. A uniform acidity is necessary daily so as to avoid daily variations in moisture content of cheese.

DIFFICULTIES OVERCOME BY ACIDULATION OF PASTEURIZED MILK.

The substance which has been found to meet all of the foregoing requirements and which appears to be unobjectionable from all standpoints is hydrochloric acid. While it might appear impracticable at first glance to acidulate milk in large quantities daily at a factory, yet upon trial this is found to be entirely practicable; and it has now been done almost daily for nearly three years, without any trouble arising from coagulation of the milk with acid at any time.

In Table 1 is shown the moisture content of green cheese obtained on 12 days from pasteurized milk by the use of calcium chlorid in the proportions suggested by Publow (see p. 14) and by the use of hydrochloric acid, using always sufficient acid to raise the acidity of the milk to 0.25 per cent calculated as lactic acid. The milk used in the two vats was taken from the same receiving vat full of milk, after thorough mixing. It was all pasteurized alike and one-half was then treated with calcium chlorid and the other with hydrochloric acid. These were then made up into cheese separately and were sampled for moisture at the time the cheeses were dressed, after pressing one hour.[1] From the table it can be seen that whenever the acidity of the milk used was low (0.16 to 0.18 per cent) the moisture content of the cheese made with calcium chlorid was high (40 to 44.45 per cent), and when the acidity was high (0.21 to 0.23 per cent) the moisture content was low (38 to 40 per cent). But in all cases where hydrochloric acid was added instead of calcium chlorid the moisture content of the curd was 37.5 to 40 per cent, whether the natural acidity of the milk was high or low.

[1] The correctness of this method of sampling cheese for the moisture test is demonstrated in the latter part of this bulletin.

TABLE 1.—*Comparison of moisture content and quality of cheese made with calcium chlorid and with hydrochloric acid.*

Date made.	Acidity of milk when pasteurized.	How made.	Moisture content of dressed cheese.	Score.		Criticism.	
				Flavor.	Texture.	Flavor.	Texture.
1911.	Per ct.		Per cent.				
Aug. 18	0.165	Calcium chlorid	42.25	38	26	Flat, pungent	Curdy, loose, weak.
Do	.165	Hydrochloric acid.	37.70	41½	27½	Clean	Trifle loose.
Aug. 22	.165	Calcium chlorid	42.35	40	26	Flat, lacking	Weak, sticky.
Do	.165	Hydrochloric acid.	38.80	41	27½	Clean and O. K	Trifle weak.
July 28	.17	Calcium chlorid	41.50	38	24	Lacks acid	Wet and sticky.
Do	.17	Hydrochloric acid.	37.70	41½	28	Trifle acid	Trifle sticky.
Aug. 23	.175	Calcium chlorid	44.27	39½	25½	Low, lacking	Trifle weak.
Do	.175	Hydrochloric acid.	39.20	40½	27	Trifle sharp	Do.
Aug. 24	.175	Calcium chlorid	44.27	37	25	Sour-milk flavor	Very loose, weak.
Do	.175	Hydrochloric acid.	39.62	41	26½	Trifle sharp	Trifle weak.
Aug. 25	.175	Calcium chlorid	44.45	41½	26½	Clean and O. K	Sticky, loose, short.
Do	.175	Hydrochloric acid.	39.02	41½	28	O. K	
Aug. 11	.185	Calcium chlorid	42.90	40	25	Bitter, lacks acid	Coarse, loose.
Do	.185	Hydrochloric acid.	39.90	41½	28	O. K	
Sept. 4	.190	Calcium chlorid	41.50	39	26	Sweet, bitter	Weak, mechanical holes.
Do	.190	Hydrochloric acid.	39.95	41½	27½	Acid aftertaste	Mechanical holes.
Aug. 17	.21	Calcium chlorid	39.20	41	26	Tastes salty	Weak and sticky.
Do	.21	Hydrochloric acid.	39.62	41	26½	do	Loose, sticky.
Aug. 16	.21	Calcium chlorid	38.70	39	26½	Vinegar flavor	Sweet holes.
Do	.21	Hydrochloric acid.	38.60	41½	27	Clean and O. K	Trifle loose.
Aug. 28	.22	Calcium chlorid	40.60	41	26½	Trifle bitter	Short, sticky.
Do	.22	Hydrochloric acid.	39.95	41	27½	do	Trifle short.
Aug. 7	.31	do	39.05				
Aug. 10	.187	do	37.58				
Aug. 21	.215	do	38.67				
Average		Calcium chlorid	42.00	39.45	25.73		
Do		Hydrochloric acid.	38.95	41.23	27.36		

From the above table it is evident that when milk is acidulated with hydrochloric acid after pasteurization, as in the new method, the moisture content of the green cheese is not affected by the ripeness of the milk before pasteurization and is quite constant between 37.5 and 40 per cent. This advantage does not attend the use of calcium chlorid. The daily variations of moisture content shown in column 4, which are between 37.5 and 40 per cent, are doubtless due to causes other than acidity, and did not noticeably affect the quality of the cheese. The scores and criticisms show that the cheese made with calcium chlorid was neither as uniform nor as good in quality as that made with hydrochloric acid.

The addition of hydrochloric or lactic acid to cream to raise its acidity without delay, preparatory to churning, was attempted by Babcock in 1888.[1] The addition of a commercial acid to raw milk to raise its acidity without waiting for bacterial action was suggested to the writer in 1905 by Dr. S. M. Babcock, chief chemist of the Wisconsin Experiment Station, and during the years 1905–6 the effort was made, following the suggestion of Dr. Babcock, to avoid the necessity for ripening milk for cheese making at the factory and

[1] Babcock, S. M. Churning tests. Wisconsin Agricultural Experiment Station, Fifth Annual Report, 1888, p. 111-121. Madison, 1888. See p. 118. See also patent granted to Müller, Milch-zeitung, vol. 23, no. 19, p. 301, Bremen, May 12, 1894; also notes on this subject in same volume, pp. 425, 464, 701, 750.

to substitute for such ripening the addition of a commercial acid to the milk as soon as it was received. Immediately after acidulating the milk it was heated to 86° and rennet was added and the process completed in the usual manner. These experiments showed conclusively that a commercial acid such as hydrochloric acid can be added to milk without in any way damaging the quality of the cheese obtained. However, the quality of cheese obtained from overripe or tainted milk was not improved by the use of the acid, and it was concluded that acidulation alone does not offer sufficient advantages to warrant its recommendation to cheese makers. The addition of acids to pasteurized milk for cheese making was begun by the writer in 1907.

Pasteurization and acidulation of milk appear to be complementary processes, each supplying what the other lacks and together forming the basis of an improved method of cheese making.

Since the use of calcium chlorid in pasteurized-milk cheese will not be referred to again in this paper, two other points will be mentioned here in which the use of hydrochloric acid is more advantageous. These are: First, that the hydrochloric acid curds always begin to thicken 6½ to 7 minutes after rennet is added, while with calcium chlorid the first visible coagulation occurs earlier if the milk used is very ripe and later if the milk is sweet, thus varying from day to day, as shown in Table 2. Second, the percentage of fat lost in the whey is on the average about 0.14 per cent greater in the method using calcium chlorid than when hydrochloric acid is used, as also shown in Table 2. This is probably because calcium chlorid curds are always more mushy and easier to break up in stirring than curds made with hydrochloric acid. The latter are really superior in this respect to curds obtained by the regular factory methods.

TABLE 2.—*Comparison of calcium chlorid with hydrochloric acid as to their effects on cheese made with pasteurized milk.*

Date.	Time required for visible coagulation after adding rennet.		Per cent of fat in whey at time of drawing whey and matting curd.		Acidity of milk used.
	Calcium chlorid.	Hydrochloric acid.	Calcium chlorid.	Hydrochloric acid.	
1911.	*Minutes.*	*Minutes.*	*Per cent.*	*Per cent.*	*Per cent.*
July 28	14	7	0.23	0.13	0.17
Aug. 11	15	7	.35	.14	.185
16	6	7	.16	.12	.21
17	4	7	.21	.14	.21
18	14	7	.32	.19	.165
22	14½	7	.32	.18	.165
23	18	7	.39	.20	.175
24	18	7	.42	.20	.175
25	16	7	.38	.16	.175
28	6½	7	.17	.13	.22
Average..	....	....	.295	.159	....

THE PASTEURIZATION PROCESS.

PASTEURIZATION IN A DISCONTINUOUS OR "HELD" PASTEURIZER.

In May, 1907, one day's milk supply was divided in two portions, one of which was made up by the regular method and the other was pasteurized for 18 minutes at 160° F. and acidulated with hydrochloric acid. The pasteurized vat gave the best-flavored cheese after curing, though it was inferior in texture to the other. On March 12 and 27, 1908, milk pasteurized at 140° for 20 minutes and then acidulated gave such good cheese that a systematic study of the combined process of pasteurization and acidulation was begun in July, 1908. Cheese was made from milk pasteurized at 140° F. for 20 minutes, either in a Potts pasteurizer or in the cheese vat, by running first steam and then cold water into the jacket. At the same time part of the milk supply after mixing and dividing was used for making cheese by the regular methods. The scores given to the two lots of cheese thus obtained are shown below:

TABLE 3.—*Comparison of flavor and texture of cheese made from raw milk and from milk pasteurized at 140° F. for 20 minutes.*

Date made.	Pasteurized cheese.		Regular make.	
	Flavor.	Texture.	Flavor.	Texture.
1908.				
July 16	38.3	26.2	36.2	27.8
17	40.0	27.0	38.5	26.25
18	41.7	27.5	39.25	27.0
20	40.8	26.3	37.3	26.75
21	41.2	26.0	41.2	26.2
22	41.3	26.8	38.0	26.75
23	40.8	26.7	39.5	26.5
24	41.0	27.25	38.3	26.25
31	40.25	26.25	36.5	26.5
Average..	40.59	27.00	38.30	26.66

The scoring was done by J. W. Moore and F. W. Laabs. In every case but one the pasteurized cheese had better flavor and there was little difference in texture between the two lots.

CONTINUOUS AND "HELD" PASTEURIZATION COMPARED.

On account of the large volume of milk which must be handled daily in a cheese factory, and the greater expense involved in providing arrangements of sufficient capacity for heating and cooling 5,000 to 7,000 pounds of milk at one time as compared with the small cost of a continuous pasteurizer, most of the later work was done with continuous pasteurizers. These can be used for handling any required volume of milk, a larger quantity simply necessitating a

longer time for running. At the present time they are believed preferable for cheese-factory use over any form of intermittent pasteurizer yet devised. Good results had been obtained by pasteurization at 140° for 20 minutes, but since continuous pasteurization seemed the more practical factory method, it was determined to use both methods in comparison on the same milk for several days. On eight days, between July 16 and 24, 1908, half of the milk was pasteurized at 140° for 20 minutes and the other half at either 150°, 160°, or 170° in the continuous machine. The effectiveness of the two methods of pasteurization was judged from the increase in acidity observed in the whey within the time from cutting curd to drawing whey specified in each case.

TABLE 4.—*Increase of acidity after pasteurization by continuous and by held processes.*

Date.	Milk held at 140° for 20 minutes.		Milk pasteurized at 150°. Instantaneous.		Milk pasteurized at 160°. Instantaneous.		Milk pasteurized at 170°. Instantaneous.	
	Increase.	Time.	Increase.	Time.	Increase.	Time.	Increase.	Time.
1908.	*Per ct.*	*H. m.*	*Per ct.*	*H. m.*	*Per ct.*	*H. m.*	*Per ct.*	*H. m.*
July 16	0.11	2 57	....	....	0.055	3 0	....	....
17	.068	2 17	....	....	.03	2 59	....	....
18	.055	2 17	....	....	.03	2 46	....	....
20	.01	2 31	....	....	....	....	0.01	3 30
21	.02	2 19	....	....	....	....	.01	3 30
22	.03	2 21	....	....	....	....	.035	3 20
23	.078	2 10	....	....	....	....	.053	3 8
24	.018	2 30	0.01	2 40	....	....	....	....

From the above it can be seen that where milk is highly inoculated when raw, as on July 16, 17, 18, and 23, the acidity of the whey rose 0.05, 0.06, 0.07, and 0.11 per cent in about 2¼ hours after pasteurizing at 140° for 20 minutes, while it rose only about half as high in 3 hours after pasteurizing at 160° or 170° in the continuous machine.

A further substantial difference between curds from milk pasteurized on the one hand at 140° for 20 minutes and on the other at 160° in the continuous machine is that the former curds often become mellow and greased on the surface and leak white whey after milling, in this respect resembling some raw-milk curds. It was supposed at first, from analogy to ordinary factory methods, that the curd which became mellow and somewhat greased on the surface and which leaked more or less white whey was more likely to turn out well than the other, which was supposed to be lacking in acid or acid-forming bacteria. The observation was made that a curd from milk pasteurized at 170° and afterwards treated with 5 per cent starter did not become mellow in the least, while curds from the same day's milk pasteurized at 140° for 20 minutes and then treated with three-

fourths per cent starter, became very mellow and abundantly greased before milling. It was judged unnecessary, thereafter, to wait for mellowness or any other evidence of bacterial action or acid development in a pasteurized-milk curd. If a sufficient proportion of starter has been added after pasteurization, it is perfectly certain that the bacteria are present in the curd, and will take part in the curing on the shelf. From this point of view the mellowness which the 140° curds occasionally exhibit is to be regarded as objectionable and as evidence of lack of uniformity between different days' make, and since this never occurs with milk pasteurized at 160° in the continuous machine the latter appears preferable.

The cause for the greater increase of acidity in whey after cutting curd from milk pasteurized at 140° for 20 minutes, as shown above, is no doubt the fact that the milk thus pasteurized contained more living, active bacteria than that pasteurized in the continuous machine. Samples were taken for bacteriological count in every case immediately after pasteurizing, and then three-fourths per cent of starter was added to each vat, followed immediately by rennet as soon as the vat could be heated. Bacterial counts were made on these samples by Mr. L. D. Bushnell, bacteriologist, as follows:

TABLE. 5.—*Number of bacteria per cubic centimeter in raw and pasteurized milk.*

Date.	Raw milk.	Pasteurized milk.		
		At 140° for 20 minutes.	In continuous machine.	
1908.	*Number per c. c.*	*Number per c. c.*	*Number per c. c.*	*° F.*
July 17	102,000,000	2,206,000	652,000	160
18	72,000,000	2,620,000	1,960,000	160
20	119,000,000	262,000	200,000	170
21	30,000,000	33,000	9,200	170
22	173,000,000	320,000	38,000	170
23	360,000,000	15,320,000	1,300,000	170
24	65,000,000	62,000	1,100,000	150

SELECTION OF BEST TEMPERATURE FOR PASTEURIZATION IN THE CONTINUOUS MACHINE.

The temperature selected should be high enough to insure that the ripening of the milk shall be uniformly checked daily, regardless of the bacterial content of the milk used, and it should not be so high as to injure the quality of the cheese. Tests were made as follows: On several days the milk supply after mixing was divided into four lots, one of which was made up by regular methods, the others were pasteurized at 140°, 150°, and 160° and made up in separate vats. The cheese after curing was examined by several

expert cheese judges, including Messrs. U. S. Baer, Robert McAdam, H. J. Noyes, F. W. Laabs, and Gottlieb Marty, whose scores are given in Table 6:

TABLE 6.—*Quality of cheese made from raw milk and from milk pasteurized at different temperatures in the continuous-disk machine.*

Date.	Regular make.		Pasteurized at—					
			140° F.		150° F.		160° F.	
	Flavor.	Texture.	Flavor.	Texture.	Flavor.	Texture.	Flavor.	Texture.
1908. July 14	....	....	40.0	28.5	41.5	28.5	43.0	28.5
15	40.0	28.5	40.5	28.5	41.0	29.0	41.0	29.0
16	36.0	27.0	38.0	28.0	40.0	29.0	41.0	29.0
17	36.0	28.0	38.0	28.5	41.0	29.0	42.0	29.0
20	38.0	28.5	40.0	28.5	41.0	28.5	42.0	29.0
21	39.0	29.0	41.0	28.5	41.0	28.5	41.5	29.0
22	35.0	28.0	37.0	28.0	38.0	28.0	39.0	27.5
15	38.0	27.0	....	....	....	....	41.0	27.5
	40.0	26.0	....	....	....	....	44.0	28.0
	40.0	26.0	....	....	....	....	42.0	28.0
16	38.0	26.0	....	....	....	....	40.0	27.0
	38.0	24.0	....	....	....	....	44.0	28.0
	36.0	27.0	....	....	....	....	41.5	28.5
17	37.0	26.0	....	....	....	....	38.0	23.0
	40.0	26.0	....	....	....	....	44.5	29.5
	35.0	26.5	....	....	....	....	43.0	29.0
20	37.0	26.0	....	....	....	....	40.5	28.0
	42.0	27.0	....	....	....	....	44.0	29.0
	33.0	28.0	....	....	....	....	41.0	28.0
21	36.0	28.0	....	....	....	....	40.0	28.0
	37.0	25.0	....	....	....	....	40.0	27.0
	39.0	26.0	....	....	....	....	44.0	29.0
	36.0	28.0	....	....	....	....	37.0	29.5
22	42.0	28.0	....	....	....	....	40.0	25.0
	37.0	27.0	....	....	....	....	35.0	25.5
23	44.0	26.0	....	....	....	....	43.0	27.0
	36.0	27.0	....	....	....	....	40.0	28.0
24	43.0	28.0	....	....	....	....	43.5	28.5
	32.0	28.0	....	....	....	....	36.0	26.0

In nearly every case the 160° pasteurized-milk cheeses were cleaner in flavor and scored higher than the check, and in every case they scored higher than the cheeses pasteurized at 140° and 150°. The different judges scored the cheese at different ages, which will account for the wide variation of some scores. Bacterial counts made by Mr. W. H. Wright[1] show that pasteurization at 160° is more effective than at lower temperatures. This is well illustrated in Table 7.

[1] Unpublished work by W. H. Wright, instructor in agricultural bacteriology, University of Wisconsin.

TABLE 7.—*Bacterial content of milk pasteurized at different temperatures in the continuous-disk machine.*

Date.	Bacteria per cubic centimeter.			
	Raw milk.	Milk pasteurized at—		
		140° F.	150° F.	160° F.
1909.				
July 22	....	6,080,000	600,000	50,000
23	423,000,000	5,800,000	600,000	60,000
24	11,600,000	1,540,000	139,000	23,000

That the use of 160° for pasteurization is high enough to kill most of the bacteria in milk, so as to meet requirements such as those of the Chicago ordinance previously referred to on page 12, is shown in Table 8 by the following bacterial counts made by Mr. Alfred Larson in 1909:

TABLE 8.—*Bacterial content of milk before and after pasteurization in the continuous-disk machine at 160° F.*

Date.	Bacteria per cubic centimeter.		Decrease.
	Raw milk.	Pasteurized milk.	
1909.			*Per cent.*
Aug. 17	161,600,000	223,350	99.8
18	43,300,000	1,275,000	97.0
19	57,600,000	211,000	99.6
20	16,560,000	252,160	98.5
21	20,938,000	40,960	99.8
22	15,548,000	420,250	97.0
24	89,750,000	544,250	99.0
26	44,075,000	86,120	99.8
27	76,000,000	30,450	99.9
28	78,825,000	166,400	99.8
31	148,200,000	77,560	99.9
Sept. 1	25,836,000	9,670	99.9
2	51,650,000	52,125	99.9
14	27,150,000	29,250	99.9
16	77,650,000	341,600	99.6
17	38,900,000	136,350	99.6
18	124,700,000	159,880	99.8
19	60,280,000	287,500	99.5
21	185,000,000	477,600	99.6
22	63,500,000	263,200	99.7
23	45,525,000	142,300	99.7
28	18,376,000	202,600	98.8
29	13,660,000	31,000	99.7
30	980,000	14,580	98.5
1910.			
July 11	6,500,000	27,000	99.6
12	1,600,000	25,000	98.5
13	5,250,000	17,200	99.7
14	4,700,000	36,000	99.3
15	10,000,000	28,700	99.7
20	5,350,000	21,000	99.6
Sept. 19	2,525,000	30,000	98.8

Similar determinations were made by Miss A. C. Evans upon milk pasteurized in the continuous "flash" machine in 1910. They are shown in Table 9:

TABLE 9.—*Bacterial content of milk before and after pasteurization in the continuous "flash" machine at 160° F.*

Date.	Number of bacteria per cubic centimeter.		Killed by pasteurization.
	Raw milk.	Pasteurized milk.	
1910.			*Per cent.*
Aug. 3	7,950,000	4,700	99.95
4	4,250,000	15,300	99.65
5	9,750,000	142,000	98.45
9	1,500,000	4,850	99.68
11	6,450,000	11,250	99.83
15	2,850,000	43,600	98.47
16	1,017,500	12,725	98.75
17	38,000,000	700	99.99
18	4,500,000	6,000	99.87
19	3,750,000	5,500	99.86
24	18,150,000	13,800	99.93
25	14,000,000	6,500	99.96
30	47,300,000	16,200	99.97
Sept. 1	2,150,000	12,000	99.44
7	5,650,000	27,000	99.53
8	8,800,000	63,000	99.29
9	2,800,000	5,500	99.80
12	10,200,000	21,200	99.73
13	2,120,000	18,500	99.13
16	18,000,000	5,700	99.97
19	2,525,000	4,300	99.83
21	1,700,000	11,000	99.35
23	9,000,000	30,000	99.67
26	11,200,000	28,000	99.75

OBJECTIONS TO HIGHER TEMPERATURES THAN 160°–165° F. FOR PASTEURIZATION.

Cheese made by the new process from milk pasteurized at 160° has always a clean, mild flavor which suits practically all markets, and will please any consumer who likes a mild-flavored cheese. Those who are accustomed to and prefer very old high-flavored cheese would not be suited, but estimates by leading cheese dealers indicate that the proportion of consumers preferring the high-flavored cheese is very small. Most of the cheese sold to-day is only a few weeks old, because the dealers generally avoid long storage, preferring quick sales and immediate profits. This makes it practically impossible for most consumers to develop a taste for any but the new mild cheese sold in most markets. The steady sales of pasteurized-milk cheese during the past two years indicate that the flavor of the 160° pasteurized product is satisfactory for filling regular orders. Indeed, it is an open question whether most of the "high snappy" flavor often observed in old cheese is not due to the long-continued, slow development of those same taints and off flavors from unclean milk which we recognize as objectionable when they develop rapidly.

The use of higher temperatures than 160° for pasteurization was tried on several days, with the result that the flavor production in the cheese was practically prevented and the texture was inferior. The scores given to these cheeses are tabulated below:

TABLE 10.—*Quality of cheese from milk pasteurized at different temperatures in the continuous-disk machine.*

Date made.	Pasteurized at 160° F.		Pasteurized at 170° F.		Pasteurized at 180° F.	
	Flavor.	Texture.	Flavor.	Texture.	Flavor.	Texture.
1909.						
Oct. 12	40	29	38	27	35	15
13	40	29	39	28	35	15
14	40	28½	38	27	35	15

The scoring was done by Mr. F. W. Laabs. The 180° cheeses have no Cheddar flavor, but taste like first-class cottage cheese. They are so crumbly and short that it is impossible to draw a solid plug. They keep well, and it is possible that a good trade might be built by the sale of this product under some such name as "pressed cottage cheese." In all cases the use of 160° for pasteurizing milk gave better cheese than higher temperatures.

Three reasons have been suggested why the milk pasteurized at 180° gives flavorless cheese:

First. If bacteria are the essential cause of flavor production, it would appear likely that the necessary kinds of milk bacteria are destroyed by the high temperature of pasteurization.

Second. If milk enzyms such as galactase are the essential cause of flavor production, these enzyms are perhaps destroyed by the use of 180°.

Third. It may be that the casein or other native milk constituent which in normal cheese undergoes cleavage, forming the flavor-giving substances present in ripened cheese, is changed chemically either in composition or as to constitution by the heating to 180°, so that upon cleavage by bacteria, enzyms, acids, or other agencies it yields different cleavage products, lacking the flavor, etc., which characterize normal cheese.

In attempting to test the first of these possible explanations a variety of substances have been added as starters to milk after pasteurizing at 180° or other high temperatures in order if possible to supply the bacteria or enzym needed for normal curing and flavor production. Among the special starters so used were pure cultures of various bacteria; raw milk up to 20 per cent of the vat contents; cultures of bacteria isolated from milk and cheese capable of develop-

ing 1.6 per cent or more lactic acid in milk (described by Hastings[1]); cheese of various ages rubbed to creamy consistency with milk and added in different proportions through a hair sieve to the pasteurized milk in the vat; cultures made by adding cheese in this manner to milk and incubating overnight before adding to the cheese vat. All of these materials were added to milk which had been pasteurized at high temperatures up to 180°, and cheese was made therefrom; but in no case was it possible to get a normal flavor development in the resulting cheese.

The lack of flavor production under these circumstances, where many kinds of bacteria and starters were added to the pasteurized milk, seems to indicate that the casein, etc., in milk thus treated is incapable of cleavage into the flavor-giving substances; in other words, that the casein, etc., is changed chemically by the heat of pasteurization. There is additional evidence that such a change occurs.

EFFECT OF PASTEURIZATION ON THE PROPERTIES OF CHEESE CURD.

A series of cheese curds made from milk pasteurized at 160°, 170°, 180°, or higher temperatures show a regular gradation of certain characteristics. The higher the temperature of pasteurization the more tenaciously the curd retains moisture and the more difficult it is to expel the whey by ordinary means. This is shown in the following experiment: The milk in the receiving vat each morning was thoroughly mixed and then divided into three portions which were run through the pasteurizer at different temperatures and made up into cheese in different vats. Three-fourths per cent of starter was added to each vat and the milk and curds were handled in all respects as nearly alike as possible, the only difference being in the temperature of pasteurization. The curds in separate hoops were pressed in the same press, and the next morning moisture tests were made on each. This entire work was repeated on several days. The results are shown in Table 11.

TABLE 11.—*Moisture content of green cheese made from milk pasteurized at different temperatures in the continuous-disk pasteurizer.*

Date.	Milk pasteurized at—		
	160° F.	170° F.	180° F.
1909.	*Per cent.*	*Per cent.*	*Per cent.*
Oct. 12	38.4	42.2	46.6
13	37.0	39.9	43.5
14	39.0	40.7	45.5

[1] Hastings, E. G., Hammer, B. W., and Hoffman, C. Studies on the bacterial and leucocyte content of milk. Wisconsin Agricultural Experiment Station, Research Bulletin 6. Madison, June, 1909.

Each per cent given is the average of two closely agreeing duplicates. It is seen that in every case the higher temperatures of pasteurization cause higher moisture content in the green cheese. These curds were all cut with a three-eighths-inch knife and heated to 104° in the whey.

Even when a 180° curd was cut with one-fourth inch curd knives and a 160° curd with three-eighths inch knives, the moisture content in the former remained higher, as is shown in the following experiment:

TABLE 12.—*Moisture content of curds made from milk pasteurized at different temperatures in the continuous-disk pasteurizer and cut with knives of different sizes.*

Milk pasteurized at 160° F.			Milk pasteurized at 180° F.	
Time after cutting curd.		Cut into $\frac{3}{8}$-inch cubes.	Cut into $\frac{3}{8}$-inch cubes.	Cut into $\frac{1}{4}$-inch cubes.
H. m.		*Per cent.*	*Per cent.*	*Per cent.*
1 0	....	67.6	70.0	66.5
2 0	Drew whey...	60.1	63.9	61.0
2 30	....	47.2	52.4	50.6
3 30	Milled curd...	43.3	47.2	46.0
4 30	Salted curd...	42.2	45.9	44.6
4 50	Hooped curd.	41.4	45.1	43.9

Each per cent in the table is the average of two closely agreeing moisture determinations.

It is unquestionably true that pasteurized-milk curds retain moisture more tenaciously than raw-milk curds, and this effect is more marked the higher the temperature used in the pasteurization. It therefore follows that the higher the temperature used in the pasteurizer the greater will be the weight of cheese obtained from pasteurized milk. The yield per hundred pounds of milk weighed before pasteurization in each vat on three days is given in Table 13.

TABLE 13.—*Yield of cheese per hundred pounds of milk pasteurized at different temperatures.*

Date made.	Temperature of pasteurization.		
	160° F.	170° F.	180° F.
1909.	*Pounds.*	*Pounds.*	*Pounds.*
Oct. 12	12.28	13.42	15.42
13	12.10	12.97	14.53
14	11.93	12.70	14.44

It will be shown later that the yield of cheese obtained by pasteurizing at 160° is slightly greater than that obtained from raw milk, so that in this respect the effect of pasteurization is distinctly noticeable even when the lower temperature is used in the pasteurizer. Again,

among the peculiarities of pasteurized-milk curds is their decreased power to coalesce or mat when on the rack or in the press. This effect is not noticeable with milk pasteurized at 160° to 165°, but is perceptible at 170° and is very marked when the milk was pasteurized at 180° or higher. The 180° curd cubes when piled on the rack pack together like raisins or figs in a box but do not coalesce or unite, and by rubbing the finger over the mass at any time the pieces can be pulled apart. The same effect is noticed when the curd is pressed in the hoop. The pieces pack together tightly but do not unite; and at any time during the curing a plug drawn with a trier will either come out in fragments or will break into pieces instantly when handled. Instead of milling such a curd, it is merely stirred or shaken apart with the hands.

These two peculiarities of pasteurized-milk curds, which can not be remedied or avoided by any other means than reducing the temperature of the pasteurization, considered together with the impossibility of developing Cheddar flavor after pasteurization at high temperatures, appear to indicate that the pasteurization produces some deep-seated change in the chemical constitution of casein.

Another peculiarity of pasteurized milk, that of coagulating with rennet only with great difficulty, need only be mentioned in this connection, because in the process of cheese making here described the addition of hydrochloric acid to the pasteurized milk entirely restores the coagulability with rennet, producing a curd in many respects superior to and easier to handle than the curd commonly obtained in the regular way from raw milk.

From what has been said it will be seen that the use of 160° to 165° for pasteurization offers many practical advantages. It is sufficiently high to check effectually the further ripening of the milk during the next few hours, while the use of 150° is not high enough for this purpose. Furthermore, 160° gives cheese of cleaner flavor than 140° or 150° (no doubt by more effectual destruction of taint-producing bacteria) or than raw milk, as shown in Table 6. It may be mentioned also that over 99 per cent of the total bacterial content of the milk is destroyed by use of 160°, as shown in Tables 8 and 9. The 160° is preferred to 170° or 180° because the cheese obtained by the use of 160° is more nearly like the best American cheese in moisture content (see Table 11) and in texture and flavor. (See Table 10.)

So far as it is possible to say at the present time, the use of 160° is sufficient to kill most probably 99 per cent of the gas and taint-forming bacteria in milk. It can not be claimed that they are all killed, because it is true that when very unclean milk is handled by this process the cheese sometimes shows slight traces of unclean flavors, though not enough to affect the market value. While gas and pin holes have often been seen during the seasons of 1909, 1910,

and 1911 in cheese made by regular methods at this factory, no gas whatever was seen in any curd or cheese made during 1909 or 1911, and the gassy cheese obtained, nine days in succession, in 1910 was demonstrated to be due to the use by mistake of a gassy starter which was added to the milk after pasteurization. The fault arose at that time from the inefficient means then at hand for preparing and heating milk for propagation of the starter. An improved steam sterilizer was at once set up for this purpose, which prevented all further difficulty of this sort during the past two years.

The temperature finally selected as most completely securing the advantages and avoiding the disadvantages of pasteurization for cheese making is 160° to 165° F. In practice the pasteurizer is set running at 163° and held there as closely as possible.

THE DIFFERENT TYPES OF CONTINUOUS PASTEURIZERS USED.

Two different pasteurizers were used in this work with entire success, being apparently equally effective in producing the desired results at 160° to 165°. These were a disk machine of 2,000 pounds per hour capacity and a "flash" machine of 1,200 pounds capacity per hour. (See Pls. II and III.) The choice between these two types of pasteurizing machines for use in this process appears to depend upon their relative cost and ease of operation and cleaning, rather than upon any difference in effectiveness. They were used alternately on successive days for several weeks, and on three days, September 1, 12, and 19, 1910, the milk was divided, one-half being run through each. The cheese was first class in each case and showed no differences that could be traced to the use of different machines.

THE ACIDULATION PROCESS.

THE STANDARD ACIDITY OF MILK FOR CHEESE MAKING.

Milk as it flows from the pasteurizer varies daily in acidity and is lacking in bacteria of the lactic-acid type, needed to aid in cheese curing. By the addition of sufficient hydrochloric acid to raise the acidity of the milk to 0.25 per cent (as lactic acid) after pasteurizing, and of three-fourths per cent of a first-class starter, the pasteurized milk is brought daily into standard condition both as to acidity and bacterial content for cheese-making purposes. The reasons for adding acid and starter as specified will now be given in detail.

The standard acidity is 0.25 per cent, and the acidity of pasteurized milk is raised to this figure rather than to 0.20 or 0.30 per cent for the following reasons:

First. In regular cheese making the acidity of whey when drawn is, on the average, about 0.17 per cent, corresponding to an acidity

of milk of about 0.25 per cent. Anyone can test the correctness of this statement by transferring a pint of milk from a cheese vat, just before adding rennet, to a small tin pail, keeping the milk sample at the same temperature as the vat and titrating the milk in the pail as well as whey from the vat at intervals. When the whey reaches 0.17 per cent the milk reaches nearly 0.25 per cent.

The control of acidity at the instant the whey is drawn is commonly regarded as most important in regular cheese making. With milk pasteurized at 160° there is little or no increase of acidity (usually about 0.01 per cent) in whey, before the whey is drawn. The acidity of milk is adjusted to 0.25 per cent in this process after pasteurizing in order to parallel ordinary working conditions at the time of drawing the whey.

Second. Mixed milk in the factory cheese vat is commonly at 0.16 to 0.18 per cent acidity when received, although often at 0.19 to 0.21 per cent. It should never be over 0.23 per cent acidity. It is found that an addition of hydrochloric acid equal to at least 0.02 per cent of lactic acid is required to restore the coagulability with rennet to such milk after pasteurization, but the daily addition of only 0.02 per cent of acid would leave the milk of varying acidity, which is objectionable. If 0.20 per cent were adopted as the standard acidity, after adding 0.02 per cent in the form of hydrochloric acid, this rule would exclude from use all milk having a higher acidity than 0.18 per cent when received, which it is not desirable to do. Only rarely is a vat full of milk at 0.23 per cent acidity received at any factory, but even such milk can be handled in the routine manner at the standard acidity of 0.25 per cent by adding the required 0.02 per cent of hydrochloric acid after pasteurization.

It might be stated as a matter of record, not as a precedent for factory practice, that vats of milk of 0.24 to 0.28 per cent acidity when received have been successfully made up into good cheese without varying the process in any particular, excepting that only enough acid is added after pasteurization to raise the acidity 0.01 per cent, which is sufficient to restore the rennet coagulation to such ripe milk. The only apparent limit of acidity for milk to be handled by this process is that the milk should not, of course, be sour enough to curdle in the pasteurizer, and this limit is reached at or about 0.30 per cent.

However, it should be recognized by everyone that milk that has reached 0.30 per cent or even 0.25 per cent acidity before it gets to the cheese factory must have received very poor care and attention on the farm and must be entirely unfit for cheese making from a sanitary point of view.

COMPARISON OF DIFFERENT KINDS OF ACIDS FOR USE IN CHEESE MAKING.

Of the more common acids—sulphuric, hydrochloric, and phosphoric—the first is the least convenient to handle, especially in a cheese factory, because of the great amount of heat liberated when it is diluted, and the impossibility of diluting it in the carboy in which it is received. Hydrochloric acid is much better in this respect as it can be readily diluted with an equal volume of water by pouring the water into the acid with no danger and very little heat evolution. Thus diluted it fumes very little, if at all, and can be readily and accurately standardized by titration with normal caustic soda and phenolphthalein indicator. Phosphoric acid can be purchased in carboys of about 50 per cent strength, requires no dilution in the carboy, and liberates little or no heat when diluted.

The choice between hydrochloric acid and acid made from phosphorus is greatly in favor of the former because of the high cost of the latter. Recently, however, phosphoric acid made from bone ash or bone black has been put on the market in this country, containing about 45 per cent free phosphoric acid and less than 1 per cent each of hydrochloric acid, sulphuric acid, and phosphates of iron and alumina, this product being offered at 6 cents a pound in paraffined barrels. The price of this acid is very nearly the same as that of chemically pure hydrochloric acid for equal neutralizing power.

Chemically pure hydrochloric acid is and has been for years a standard article of manufacture, whose purity is tested daily by use in hundreds of laboratories. On the other hand, the manufacture of phosphoric acid from bone ash in a form free from objectionable impurities has been accomplished only very recently.

A number of cheeses were made with phosphoric acid, but these showed no advantage over those made with hydrochloric acid; indeed they seemed to have a slight peculiarity of flavor, as a rule, after curing. Most of the cheeses made from pasteurized milk have so far been made with hydrochloric acid, and the use of this acid is described and recommended in the present bulletin.

The selection of hydrochloric acid was made because it is cheap and more easily obtained than any other chemically pure acid, and being a natural constituent of gastric juice in the human stomach, no objection could be raised on sanitary or other grounds against its use in this process.

THE PROPORTION OF HYDROCHLORIC ACID REQUIRED DAILY.

It is necessary to determine first what the acidity of each vat of the mixed milk is, in order after pasteurizing to add the requisite quantity of hydrochloric acid to bring the acidity up to 0.25 per cent. Where only one vat of milk is to be pasteurized and only one workman

is employed it is probably better to weigh in all the milk then stir the vat well and take out a half cupful of milk for the acid test.

Where two men are employed and it is desired to start the pasteurizer running as early as possible (before the receiving vat is full), the intake man should take from each weigh can of milk a sampling tube full, mixing these samples in a pint jar. The acidity of this mixed sample will then be the same as the average acidity of all the milk run into the vat. As soon as one vat full of milk (say 5,000 pounds) has been run from the weigh can into the receiving vat, the pint jar containing the sample for the acid test is handed from the intake to the man running the pasteurizer, together with the total weight of milk run into that vat. The pasteurizer was started when perhaps only half of this milk had been received, but the receiving vat is still about half full, and after making the acid test on the sample the operator can tell exactly how much more hydrochloric acid must be added, while pasteurizing the remaining milk in order to bring the acidity of the whole vat up to the right point, or 0.25 per cent.

TESTING MILK FOR ACIDITY.

In determining the acidity of milk, measure a 17.6 cubic centimeter pipette full of milk sample into a white china cup, which should be shallow and wide rather than narrow and deep. Add two drops of phenolphthalein indicator and while shaking or stirring the milk in the cup run in tenth-normal alkali (Manns's solution) from a burette, rapidly at first, and later by single drops, until the faint pink color produced by the last drop does not disappear on thorough mixing. The volume of tenth-normal alkali used is read from the burette, and this volume divided by 20, which can be done mentally, gives the exact acidity of the milk in per cent of lactic acid by weight. For example, if the volume of alkali solution used was 3.2 cubic centimeters the acidity is 3.2 divided by 20, which equals 0.16 per cent. Subtracting the acidity of the raw milk from 0.25 per cent shows how much the acidity of the milk is to be raised with hydrochloric acid after pasteurizing. For example subtracting 0.16 per cent from 0.25 per cent leaves 0.09 per cent, which shows that the acidity is to be increased 0.09 per cent with hydrochloric acid.

The outfit needed for testing milk is shown in Plate I. It consists of:

1. A burette with rubber tip and pinchcock; capacity 25 c. c., with $\frac{1}{10}$ c. c. graduations.
2. A 17.6 c. c. pipette as used for the Babcock test.
3. A white china teacup, which is best if shallow and wide and with flat bottom.
4. A support for the burette, which may be an iron stand and clamp, or a wooden strip with a hole in it, fastened to a window casing, as shown at the left in Plate I.

5. A rubber-stoppered bottle of Manns's solution (tenth-normal alkali) which may be purchased at $1 per gallon of dealers in dairy supplies, or may be made by diluting the normal alkali solution, which must be purchased as it is required in this process as described on page 36.

6. A 2-ounce or 4-ounce bottle of phenolphthalein indicator solution.

7. The additional outfit required for use in this process of cheese-making is also shown in the figure. It consists of 1 gallon of normal alkali (ten times as strong as Manns's neutralizer), a 50 cubic centimeter measuring flask, a 500 cubic centimeter measuring cylinder, and a 2 cubic centimeter pipette, which should be accurately made. A gallon of normal caustic alkali contains about 5 ounces of caustic soda, worth about 15 cents, and should cost the cheese maker no more than a gallon of tenth-normal solution—that is, about $1.

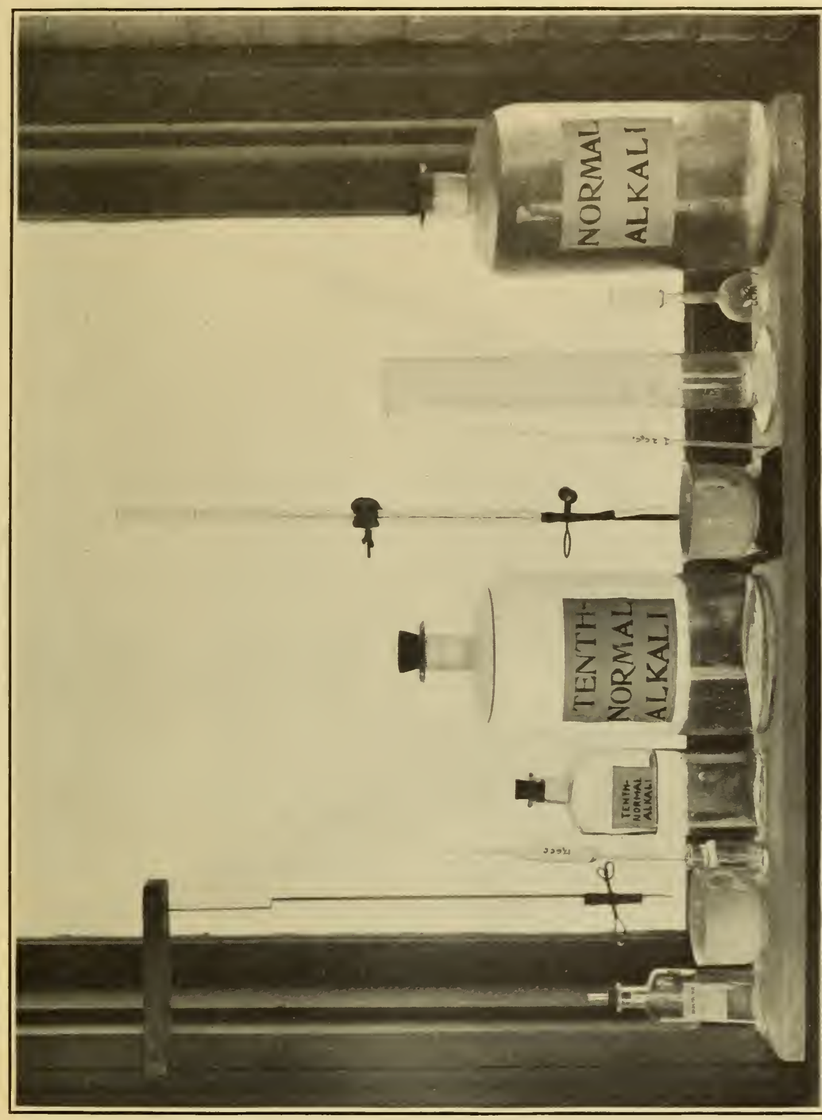
PRESERVING THE TENTH-NORMAL SOLUTION.

Instead of using the large bottle of tenth-normal solution to fill the burette with, it is much better to get a smaller bottle, holding 6 or 8 ounces, also provided with a rubber stopper, and to fill this smaller bottle occasionally from the larger bottle, which is then put away, tightly stoppered, in a safe place. The small bottle is kept near the burette and used daily in filling it, and the large bottle is thus protected from unnecessary exposure, loss of strength, and from danger of spilling. The use of two bottles in this manner has proven most satisfactory in this laboratory and dairy school during the past four years. It is recommended [1] as a means of avoiding loss of strength through exposure to the air, which has heretofore been the greatest difficulty to overcome in the use of Manns's test in the cheese factory.

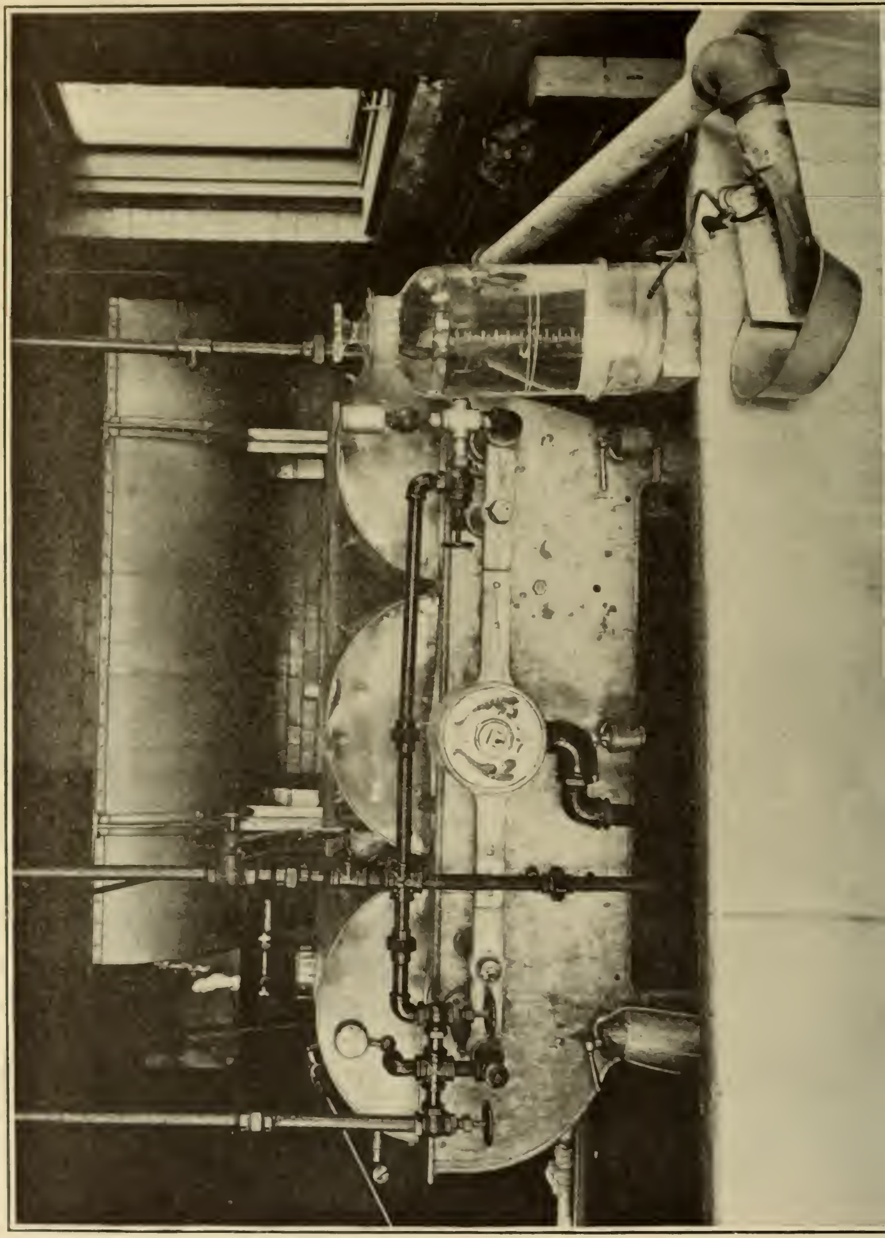
DILUTING NORMAL ALKALI TO TENTH-NORMAL.

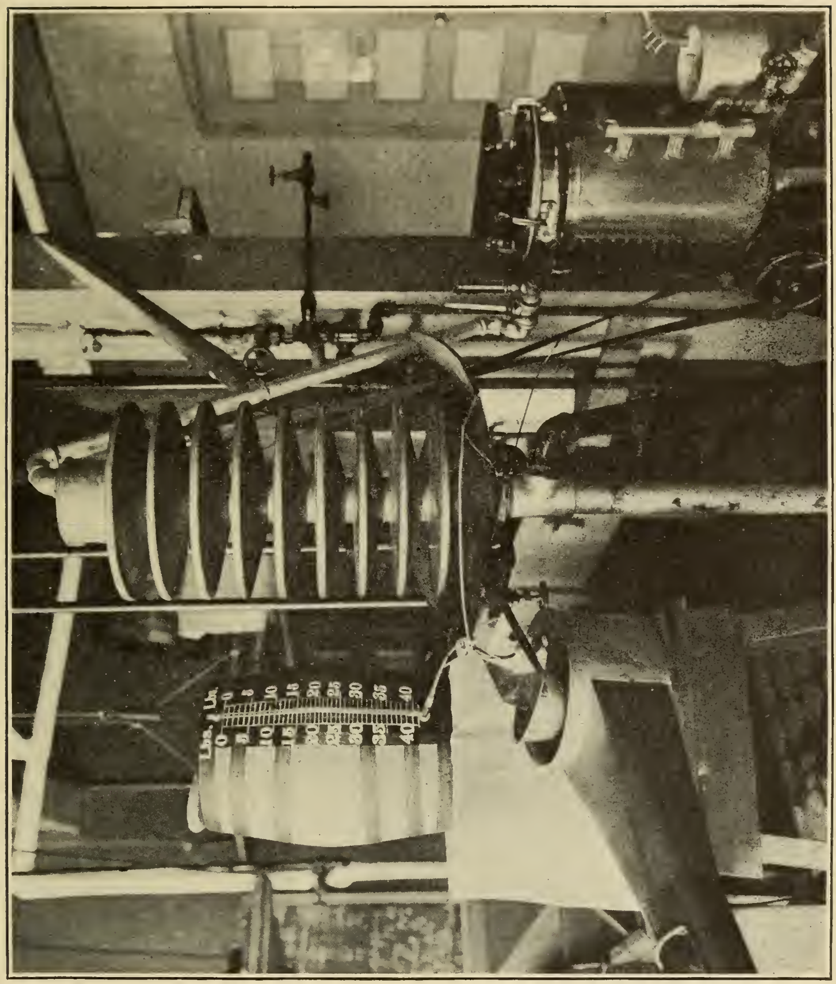
One may prepare tenth-normal alkali by diluting the normal alkali as follows: Pour into a 500 cubic centimeter graduated cylinder exactly 50 cubic centimeters of the normal solution measured in the 50 cubic centimeter flask. Add at once 450 cubic centimeters of pure water, either rain water or condensed steam. Pour the mixture into a clean glass bottle, mix by shaking, and keep stoppered with a rubber stopper to avoid loss of strength by exposure to air. If the mixture is muddy or turbid, the water used in diluting was not pure. A slight turbidity may be neglected.

[1] Sammis, J. L. The preservation of Mann's alkaline solution in cheese factories. Hoard's Dairyman, vol. 40, No. 41, p. 1200. Fort Atkinson, Wis., Nov. 12, 1909.



OUTFIT USED FOR TESTING MILK FOR ACIDITY (MANN'S ACID TEST) AND IN TESTING STRENGTH OF HYDROCHLORIC ACID USED IN CHEESE MAKING.





THE CONTINUOUS "FLASH" PASTEURIZER AND APPARATUS USED IN ACIDULATING PASTEURIZED MILK.

ADDING ACID TO MILK AFTER PASTEURIZATION.

For this purpose the acid of normal strength is placed in an acid-proof container on a shelf near the outlet of the cooler. A glass bottle or a paraffined wooden cask can be used, as shown in Plate III. The container has a small opening on one side near the bottom, through which the acid is drawn by a rubber tube of one-eighth or one-quarter inch internal diameter closed by a screw pinchcock. On the outside wall of the container, beginning at the top, a scale is engraved or otherwise permanently attached, with graduations showing pounds, halves, and quarters of acid delivered. If the container is opaque, a glass level-tube placed outside near the scale shows the acid level within at any time. The capacity of the acid container should be about 10 gallons for use with a 7,000-pound vat of milk. In addition, a two-quart tin pan is connected by means of a short piece of conductor to the cooler outlet. The milk from the cooler and acid from the container are thoroughly mixed in the conductor and mixing pan, from which the acidulated milk overflows and runs into the cheese vat.

In order to avoid coagulation of milk with acid, the acid is added from a jet so as to strike the cooled milk while the latter in a thin stream is moving rapidly down the short, steeply inclined piece of open-conductor pipe. The mixture then enters the mixing pan and its direction is abruptly changed twice, thus securing thorough mixing of milk and acid before it flows over the edge of the pan into the cheese vat.

In using this acidulator there is never any danger of coagulation if the operator remembers always to shut off the acid before the milk flow stops. It has been repeatedly shown that 2 pounds of acid, or twice as much as commonly required, can be safely added in this manner to 100 pounds of milk at 60° to 80° F. without causing coagulation. If any small particles of curd are formed, they rise to the surface of the milk when quiet in the vat and can be plainly seen. They can then be taken up with a hair sieve and rubbed through the sieve into the milk without causing loss of yield. In practice, the acidity of the vat of milk, when all in and stirred, always comes between 0.24 and 0.26 when attempting to make it 0.25 per cent, and this degree of accuracy is entirely satisfactory.

CALCULATING THE AMOUNT OF ACID TO BE ADDED.

To calculate how many pounds of normal hydrochloric acid are required by any vat of milk after pasteurizing, it should be remembered that 1 pound of the acid added to 100 pounds of milk will raise its acidity just nine hundredths (0.09) per cent. From this it is easy

to see that for 2,500 pounds of milk, of 0.16 per cent acidity, just 25 pounds of normal strength acid will be required, and for 3,050 pounds of milk 30.5 pounds of acid will be needed, etc. If the milk showed an acidity of 0.21 per cent when raw, then subtract 0.21 from 0.25, which leaves 0.04 per cent. In this case, since the milk is riper to start with, less acid will need to be added; only four-ninths of a pound of acid for each 100 pounds of milk will be necessary to bring the acidity up from 0.21 to 0.25 per cent. In any case the weight in pounds of acid required is equal to $\frac{0.25 - \text{acidity of raw milk}}{.09} \times \frac{\text{weight of milk}}{100}$, or $0.25 - \text{acidity of raw milk} \times \frac{\text{weight of milk}}{9.0}$. Stated in words the rule is, divide the weight of milk by 9 and multiply by 0.25 minus the acidity of the raw milk.

The following table shows the amount, in pounds, of normal acid required to be added for each 100 pounds of milk when the acidity of the latter before pasteurizing is 0.15, and for each one-hundredth increase up to 0.27:

TABLE 14.—*Weight of normal acid required to be added for each 100 pounds of milk.*

Acidity of milk when pasteurized.	Weight of normal acid added to 100 pounds of milk.	Acidity of milk after the addition of acid.
Per cent.	*Pounds.*	*Per cent.*
0.15	1.11	0.25
.16	1.00	.25
.17	.88	.25
.18	.77	.25
.19	.66	.25
.20	.55	.25
.21	.44	.25
.22	.33	.25
.23	.22	.25
.24	.11	.25
.25	.11	.26
.26	.11	.27
.27	.11	.28

Where milk appears to be of, say, 0.175 per cent acidity when received, it is treated as if it were at 0.17 per cent, dropping the 0.005 out of the calculation.

The following table, conveniently posted, may aid in calculating the weight of acid required for any weight of milk at any acidity:

TABLE 15.—*Weight of normal hydrochloric acid required for stated quantities of milk at stated acidities.*

Weight of milk.	Hydrochloric acid required when acidity is—										
	0.27 to 0.24.	0.23.	0.22.	0.21.	0.20.	0.19.	0.18.	0.17.	0.16.	0.15.	0.14.
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
10,000	11.1	22.2	33.3	44.4	55.5	66.6	77.7	88.8	100.0	111.1	122.0
9,000	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0
8,000	8.9	17.8	26.7	35.6	44.4	53.3	62.2	71.1	80.0	88.9	97.8
7,000	7.8	15.5	23.3	31.1	38.9	46.7	54.4	62.2	70.0	77.8	85.6
6,000	6.7	13.3	20.0	26.7	33.3	40.0	46.7	53.3	60.0	66.7	73.3
5,000	5.6	11.1	16.7	22.2	27.8	33.3	38.9	44.4	50.0	55.5	61.1
4,000	4.4	8.9	13.3	17.8	22.2	26.7	31.1	35.5	40.0	44.4	48.9
3,000	3.3	6.7	10.0	13.3	16.7	20.0	23.3	26.6	30.0	33.3	36.7
2,000	2.2	4.4	6.7	8.9	11.0	13.3	15.6	17.8	20.0	22.2	24.4
1,000	1.1	2.2	3.3	4.4	5.5	6.7	7.8	8.9	10.0	11.1	12.2
900	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
800	.9	1.8	2.7	3.6	4.4	5.3	6.2	7.1	8.0	8.9	9.8
700	.8	1.6	2.3	3.1	3.9	4.7	5.4	6.2	7.0	7.8	8.6
600	.7	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3
500	.6	1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.6	6.1
400	.5	.9	1.3	1.8	2.2	2.7	3.1	3.6	4.0	4.4	4.9
300	.4	.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7
200	.2	.4	.7	.9	1.1	1.3	1.6	1.8	2.0	2.2	2.4
100	.1	.2	.3	.4	.6	.7	.8	.9	1.0	1.1	1.2
75	.08	.17	.25	.34	.42	.50	.60	.67	.75	.83	.92
50	.06	.11	.17	.22	.28	.33	.39	.44	.50	.56	.61
25	.03	.06	.09	.11	.14	.16	.19	.22	.25	.28	.31

To find how much normal hydrochloric acid will be needed to raise 6,754 pounds, for example, of milk of 0.17 per cent acidity to 0.25 per cent acidity, take from the table the figure given under 0.17, opposite 6,000, which is 53.3; add to this the figure opposité 700, which is 6.2; then add the figure opposite 50, which is 0.44; the total gives the number of pounds of acid required, namely, 59.9 pounds.

PREPARATION OF NORMAL HYDROCHLORIC ACID IN THE CHEESE FACTORY.

Chemically pure hydrochloric-acid solution, as purchased in carboys containing about 120 pounds each, contains about 40 per cent by weight of hydrochloric acid and 60 per cent of water, and costs about 7 cents a pound. Its strength varies somewhat, and it must be diluted with water before it can be added to milk in this process. The preparation of normal-strength acid used in cheesemaking is carried on at the cheese factory in two steps, as follows:

First step.—Remove the wooden cap from the top of a fresh carboy of acid and loosen the glass plug in the neck by tapping it on different sides very gently with a piece of wood (not metal) until it can be drawn out readily with the hand. Set an empty carboy alongside the newly opened carboy. Fill both limbs of a glass siphon with water, removing all air bubbles, and insert the two limbs into the carboys at once, as shown in Plate IV. When the siphon is in place, as shown in the lower figure, the acid will flow from the full carboy into the other until in about half an hour each is practically half full. Now fill up

each carboy nearly to the neck with water, leaving space enough beneath the neck to permit mixing the contents readily by shaking. Tip each carboy up on one edge and rock vigorously for about five minutes with the stopper out to induce thorough mixing. The liquid gets slightly warmer on mixing, and it is stoppered and left to stand overnight to cool and is then called "dilute" acid.

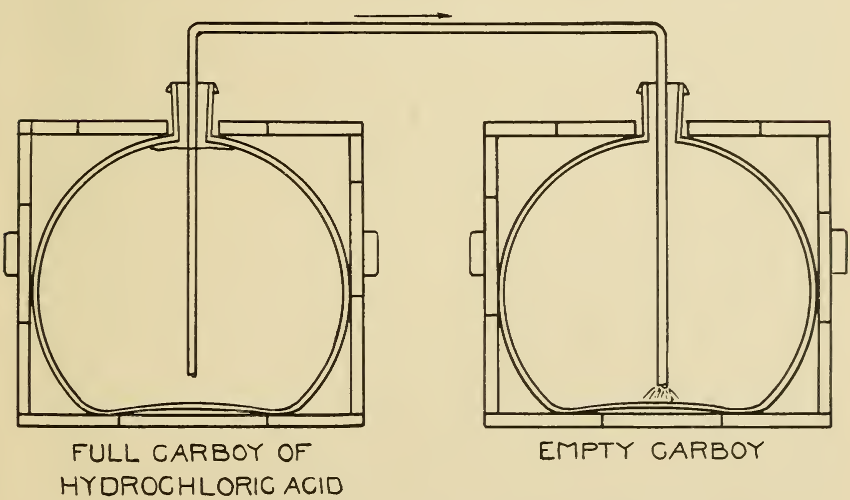
To determine how much further each carboy of dilute acid requires to be diluted with water to make it exactly "normal" in strength, set up the burette used in Manns's test, but fill it with normal alkali solution, which is 10 times as strong as that used in testing milk. Using a 2 cubic centimeter pipette, transfer exactly 2 cubic centimeters of the dilute acid from the carboy to the porcelain cup containing a little pure water, letting the pipette drain into the cup half a minute by the watch and blowing out the last drop of acid from the tip into the cup. Now add one or two drops of indicator and after reading the level of alkali in the burette, draw out the alkali from the burette, precisely as in testing milk, rapidly at first, later by single drops while shaking the cup in a circle until the last drop added produces a distinctly pink color which remains throughout the entire liquid after thorough mixing. Read and record the volume of alkali solution used. Rinse out the cup, fill up the burette, shake up the acid in the carboy for a minute and test another 2 cubic centimeters of the acid for the sake of accuracy.

If the contents of the carboy were thoroughly mixed at first, the two titrations will agree closely, not differing by more than 0.20 cubic centimeter. If they do not agree, the carboy contents were probably not well mixed at first, and should be given another very thorough shaking for five minutes, after which the titrations are repeated. Once thoroughly mixed the acid and water remain mixed, and never need to be shaken again.

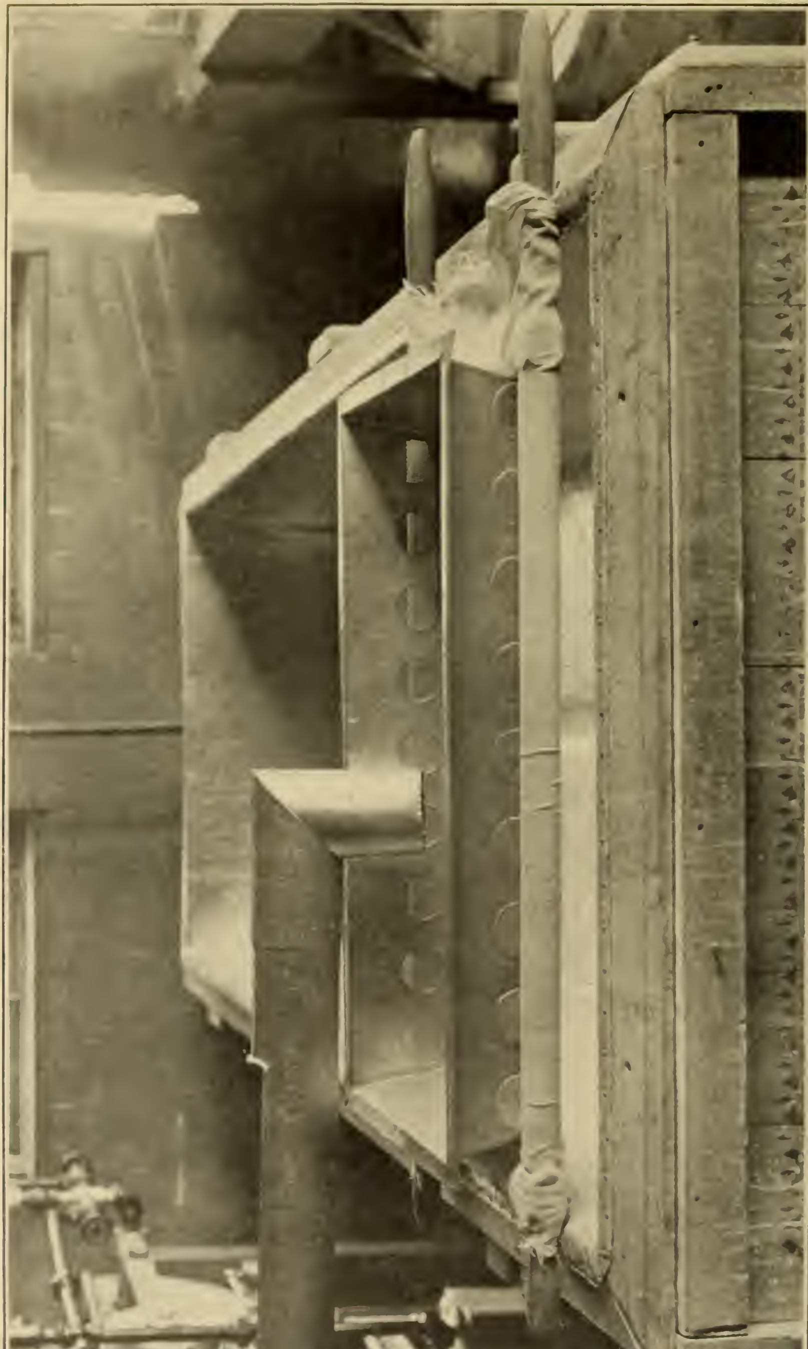
Suppose that in the two tests the 2 cubic centimeters of acid required 11 and 11.2 cubic centimeters of normal alkali to produce the pink color, the average being 11.1 cubic centimeters. Divide the volume of alkali by 2—the volume of acid used—which gives in this case $\frac{11.1}{2} = 5.55$. This means that the acid is 5.55 times as strong as it should be for normal acid, and that it must be diluted to 5.55 times its volume with water to make it exactly normal in strength.

The work described above is performed once on each carboy of dilute acid before using it for cheesemaking, and the object is to get the figure (5.55 in this case) which shows how much too strong the acid is, and how much it must be diluted to make it normal in strength.

Second step.—The second step consists in diluting up, each day, as much of the acid as will be needed for the milk on that day. This



TRANSFERRING ACID FROM FULL TO EMPTY CARBOY BY MEANS OF SIPHON.



VAT STRAINER FOR STRAINING MILK INTO RECEIVING VAT.

is performed as follows: Having determined that the dilute acid is 5.55 times stronger than normal, the acid is further diluted for use each day, adding 1 volume of acid to 4.55 volumes of water, thus making the total volume 5.55 times as great as the acid used.

To do this, measure out any convenient volume (say 500 cubic centimeters for about 2,500 pounds of milk) of the acid in a glass cylinder and add it to 4.55 times its volume of water (in this case $500 \times 4.55 = 2{,}275$ cubic centimeters water). The acid should always be measured, but if more convenient the water can be weighed in pounds if it is remembered that 453 cubic centimeters of water weigh 1 pound. In this case $\frac{2{,}275}{453} = 5.02$ pounds of water needed.

The acid and water can be mixed in the acidulator or in a wooden pail, or in a bright tin pail, if the water is put in first and the acid added later. After the proper amounts of acid and water have been poured into the acidulator, they should be thoroughly mixed at once by stirring with a wooden paddle, and once thoroughly mixed the normal acid is always ready for use. Of course the acid should not be handled in galvanized iron or aluminum vessels, as it will rust them. The undiluted acid will also discolor tinware and should be measured in the glass cylinder, as directed. The "dilute" acid is drawn from the carboy into a gallon glass bottle through a glass siphon, which is first filled with water. The water used in the siphon is so small in volume—about 1 per cent of a gallon—that it does not noticeably affect the strength of the acid.

There is nothing difficult about the preparation of normal-strength hydrochloric acid for use in cheese making, and anyone who knows how to titrate milk for acidity can learn to do this also. To test the correctness of the work when completed, transfer two cubic centimeters of the acid with a pipette from the acidulator to the porcelain cup, and titrate it with the normal alkali in the burette. The volume of alkali required should be between 1.9 cubic centimeters and 2.1 cubic centimeters, or, better, exactly equal to the volume of acid used.

The degree of accuracy required in this whole process is very easily attained, as quite satisfactory results will be obtained in acidulating milk if the normal acid used is anywhere between 0.95 and 1.05 normal.

GENERAL DIRECTIONS FOR PASTEURIZING AND ACIDULATING MILK.

The method described is well adapted for use in a large factory. At a factory handling two to three large vats of milk daily two men should be employed. The inspection and weighing of milk at the intake is performed by one man while the other makes the determitions of acidity and runs the pasteurizer. After the milk is all in and pasteurized the two men work together, heating up the vats,

adding the starter, color, and rennet to the vats at least 10 or 15 minutes apart. They cut the curds in the same order, each 25 minutes after the rennet has been added, and start the agitators in each curd as soon as cut. The vats are heated up and the whey is drawn from the vats in the same order, both men working together in putting the curds on the rack, finishing each vat of curd in time to handle the next.

If more than three vats are handled in one factory, additional help will be needed, especially for bandaging hoops, turning cheese, and other labor.

Where only one vat of milk is handled daily, the milk is run first into the receiving vat, from which it flows into the pasteurizer, through the cooler, and into the cheese vat. If two vats of milk are handled daily, the first milk received may be run into one cheese vat, from which it is pasteurized into the other cheese vat, while the milk received later is run into the steel receiving vat, from which it is pasteurized into the second cheese vat.

If three or more vats of milk are handled daily, the receiving vat and the first cheese vat are filled alternately with milk from the intake, and alternately emptied through the pasteurizer into the other cheese vats. It is only necessary to see to it that the last vat filled from the intake shall be the receiving vat in order that this last milk may be run into one of the cheese vats after pasteurization. One receiving vat is needed in addition to the necessary cheese vats wherever this process is used.

MAKING READY TO PASTEURIZE.

Since pasteurization is essentially a cleaning process, care should be taken to keep the make room, the vats, machinery, etc., and everything with which the pasteurized milk comes in contact as clean as possible.

Although milk flows intermittently from the weigh cans, it is desirable that the pasteurizer, once started, shall run continuously, with a steady milk supply, and for this purpose a receiving vat is provided. The milk should be run into the receiving vat through a strainer which will remove all flies, straw, etc., and which can not by accident fail to work properly. Such a strainer is shown in Plate V. It is set up by slipping a piece of seamless cheese bandage over the wooden frame of the vat strainer and placing the metal part on top. The metal part collects all large pieces of dirt and prevents the milk from splashing over the side. The two thicknesses of cheesecloth effectually remove finer particles of dirt. This arrangement has been used in this series of experiments for about two years and is heartily recommended. Of course the cloth should be scalded daily.

The weigh can, conductors, receiving vat, and pasteurizer should be washed daily, immediately after use, and again rinsed with clear hot water before use, if necessary. The pasteurizer and cooler and the connecting pipes should be washed thoroughly daily. Just before starting the pasteurizer each morning the operator should rinse out the cheese vat and steam it by running steam into the jacket. The pasteurizer and delivery pipes, especially those parts which are in contact with the cooled pasteurized milk, should be also scalded or steamed. This can be done by running a couple of pails of hot water into the heating compartment, heating it there to 180° or higher, and running it over the cooler without having any cold water inside the cooler.

Where only one vat of milk is being pasteurized, the acidulator may be set on the edge of the vat, but to avoid moving it, when several vats of milk are handled daily, the acidulator should be set near the pasteurizer and the acidulated milk run into the different vats through a movable conductor, as shown in Plate III.

STARTING AND STOPPING THE PASTEURIZER.

When milk enough has been received to insure a continuous supply for the pasteurizer, the latter may be started.

First, see that everything is in place and that the pump supplying water for cooling is running. Set the pasteurizer in motion, turn on a little steam, and run enough milk into the heating compartment nearly to fill it so as to register its temperature on the naked glass bulb of the thermometer placed near the exit to the cooler. Do not allow any milk at all to run into the cooler. If any does by accident, draw it out and scald the cooler with a pail of hot water.

Open the steam valve to the full running capacity. When the thermometer in the milk registers about 155° start the milk supply again and adjust so that the thermometer stands at 162° at the exit from the heater. Use care to see that no milk at all is allowed to run to the cooler at a temperature below 160°. If any irregularity occurs in starting, it is much better that the first milk should be heated higher than 160°, even up to 180°, rather than that any portion should pass over into the cheese vat without reaching 160°. It will do no harm at all if for a few minutes at first milk at 170° or 180° passes over into the cooler, because this milk will at least be thoroughly pasteurized, but if milk at 140°, or any temperature below 160°, passes over it may carry over harmful bacteria which may injure the entire vat of cheese. A file mark on the steam-valve handle is a great help in quickly adjusting the steam supply to the right point.

Once adjusted, and with steady milk and steam supply, the pasteurizing temperature remains nearly constant and requires only momen-

tary inspection every few minutes. No doubt an automatic temperature-controlling device could be used to advantage here.

Although the thermometer now supplied with some forms of pasteurizers is metal jacketed to prevent breakage, yet in all the experiments here reported this metal-cased thermometer was found to register more slowly than a naked glass-bulbed thermometer, set in a rubber stopper. The latter kind has been in use two years without breaking and is therefore preferred.

In stopping the pasteurizer for any reason, the operator should remember to stop the acidulator first, then the milk supply, and last of all the steam. If the stoppage is for long, as at the end of the day's run, the hot milk in the heating compartment is drawn out in a pail (its temperature should be 160° or above) and added to the vat. The milk in the cooler is also drained and rinsed, if desired, into the vat.

The water supply for cooling must be ample so that a thermometer placed in the milk flowing from the cooler is not above 85° at any time, and preferably at 80° or lower, since the milk in the vat can easily be heated to 85°–86° for setting with rennet, but can not so well be set, or easily cooled, if above 86°.

STARTING AND STOPPING THE ACIDULATOR.

As soon as the pasteurizer has been started and regulated the pinchcock at the acidulator is opened, allowing one or more small streams of hydrochloric acid to run into the milk. The height of the liquid in the acidulator should be marked on the glass scale with a pencil or string, when starting, and another mark placed lower down on the scale to show how much acid is to be drawn out for that vat of milk. By this means the operator can see from any part of the room when the acidulator is ready to be stopped. Always stop the acidulator before stopping the milk.

THE USE OF BACTERIAL STARTER IN THE NEW PROCESS.

THE REASON FOR ADDING STARTER IN MAKING PASTEURIZED-MILK CHEESE.

The addition of the required amount of hydrochloric acid to milk raises its acidity at once to 0.25 per cent, but does not cause any further increase of acidity at any time. Of the acid thus added, only about one-fortieth remains in the curd, the rest escaping in the whey. No chemical method has been found for increasing the acidity of a curd on the rack, so that if acid plays any important part in the cheese-curing process, it will be necessary to add bacteria to the milk in order to develop the necessary acid in the curd and cheese. A number of

experiments were performed in which the milk supply was divided and made up in different vats, using different proportions of starter. The cheese was finally scored by Mr. J. W. Moore with the following results:

TABLE 16.—*Quality of cheese made from pasteurized milk with varying amounts of starter added.*

Date made.	Cheese No.[1]	Proportion of starter.	Temperature of pasteurization.	Score.	
				Flavor.	Texture.
1908.		*Per cent.*	*°F.*		
Aug. 17	1076c	....	....	40.50	27.00
	1079	0.25	157	40.50	27.25
	1081	.50	157	41.25	27.25
	1083	.75	157	42.50	28.00
18	1085c	....	....	41.00	27.25
	1087	.25	157	41.75	27.75
	1889	.50	157	41.00	27.25
	1091	.75	157	40.25	27.00
19	1093c	....	....	40.50	27.00
	1095	.25	157	41.25	27.00
	1097	.50	157	42.50	27.75
	1099	.75	157	42.75	28.00
20	1101c	....	....	41.25	27.00
	1103	.25	157	42.50	28.25
	1105	.75	157	42.25	27.75
21	1109c	....	....	40.75	27.00
	1111	.75	157	42.25	27.25
	1113	1.00	157	42.50	27.25
	1115	1.25	157	42.50	27.75
22	1117c	....	....	39.50	27.25
	1119	.75	157	42.25	27.00
	1121	1.00	157	41.75	27.25
	1123	1.25	157	42.25	27.00
31	1157c	....	....	41.00	27.00
	1159	None.	162	41.00	27.00
	1161	.3	162	42.50	28.00
	1163	.6	162	42.50	28.00
Sept 1	1165c	....	....	39.00	28.50
	1167	None.	162	40.50	26.00
	1169	.3	162	42.00	27.50
	1170	.6	162	42.50	28.00
2	1173c	....	....	40.00	27.00
	1175	None.	162	41.00	26.00
	1177	.3	162	41.00	27.00
	1179	.6	162	41.50	27.00
	1024	3.0	....	Sour.	Color-cut.
	1026	5.0	....	Sour.	Color-cut.

[1] "c" in this column indicates raw-milk cheese.

These scores may be summarized as follows:

TABLE 17.—*Summary of scores in Table 16.*

Amount of starter.	Number of cheeses scored.	Average scores.		
		Flavor.	Texture.	Combined.
Per cent.				
0	3	40.83	26.33	67.16
0.25 to 0.30	7	41.64	27.53	69.18
.5 to .6	6	41.88	27.54	69.42
.75	6	42.04	27.50	69.54
1.0	2	42.12	27.25	69.37
1.25	2	42.37	27.37	69.75

These scores indicated that the cheese obtained by three-fourths, one, or one and a quarter per cent starter are about equally good, considering both flavor and texture, and the use of three-fourths per cent starter has been continued since August, 1908, to the present time, with good results. The starter used should be first class in quality, just beginning to thicken, containing the maximum number of lactic acid bacteria in active condition, and free from all objectionable germs or flavors.

Only a starter above criticism, such as every good cheese maker should know how to prepare, can be used with pasteurized milk. If the starter is at all tainted it is sure to damage the flavor of the cheese to some extent. With raw, badly tainted milk, especially in warm weather, a starter of only fair quality will often greatly improve the quality of a vat of cheese, but pasteurized milk is freed from practically all taints by the pasteurization, and to such milk only the best starter can safely be added.

The importance of a good starter was made apparent when, beginning June 9, 1910, nine days' make of pasteurized-milk cheese proved to be gassy and off flavor, and bacteriological examination of the starter as well as of the cheese demonstrated the presence of the same gas-forming organism in both. It was clear that the organisms in question did not pass through the pasteurizer, since their thermal death-point was found to be lower than the pasteurization temperature (160°) employed in the process. Therefore there could be no doubt that the improper preparation of milk for propagating "startoline" was the cause of the trouble in this case.

A PRACTICAL STERILIZER FOR THE CHEESE FACTORY.

The essential equipment for propagating a starter is some sort of a sterilizer, an incubator, and a supply of a dozen pint cream bottles which are best provided with fairly tight tin covers about 2 inches deep. Various different sterilizers have been recommended, the simplest being an inverted tin pail covering the bottles of milk on the steam table. For use as an incubator, a small covered shotgun can may be steamed out daily, and after placing the bottles therein and adjusting the cover it may be carried to the ice box, the cellar, a hay cooker, or any room of suitable temperature. Where bottles of starter must be handled and carried about there is always some danger of their becoming infected, and this can only be prevented by intelligent work on the part of the operator. On account of its small size a culture propagated in a bottle is often called a "startoline," meaning a little starter. A combined sterilizer, cooler, and incubator made of galvanized iron has been devised, and used in our work during the past year with entire satisfaction. Its use saves time in

handling and reduces the danger of contamination to a minimum. It is shown in figure 1.

The apparatus consists of a galvanized-iron container with cover, a movable false bottom, and with steam, water, and drain connections. Where pint bottles are used, the perforated shelf is raised and set on lugs as shown. If quart bottles are used, the perforated bottom is lowered, so that the top of the bottle always stands at the top of the sterilizer.

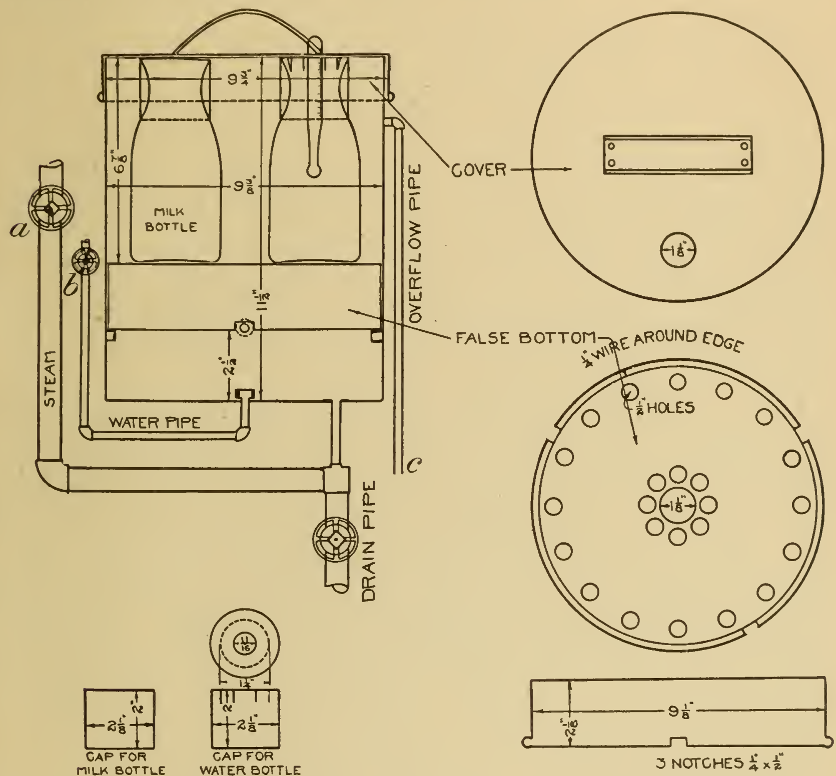


FIG. 1.—Combined sterilizer, cooler, and incubator for cheese-factory starter.

PREPARATION OF THE STARTER.

The bottles having been cleaned and filled nearly full with the best whole milk obtainable are each covered with a tin cap and set in the sterilizer, together with one bottle of water carrying the thermometer. The lid is put on and the steam turned on very slowly at first, by turning handle *a*. After the thermometer projecting through the small hole in the lid shows that the contents of the bottles are heated to 200° or above, the steam is left running for three quarters of an hour, and then turned off. To cool the bottles of sterilized milk open valve *b* and slowly run in cold water, which escapes at the overflow *c*. If the water is turned on by mistake faster than the

overflow can carry it off, the tin caps will keep it from entering the bottles of milk. When the thermometer shows that the bottle contents are cooled to about 70° the water may be turned nearly or entirely off. The bottle of "startoline" from the previous day, which has not yet been opened, is now brought in and a portion, about a tablespoonful by guess, is poured into each bottle of newly sterilized milk in the apparatus, lifting the tin caps for an instant for this purpose. The room should be free from drafts, floating dust, or other source of contamination, and the transfer should be made as quickly and carefully as possible. The cap is then replaced and the cover put on. The temperature of the water can be kept between 60° and 70° for a few hours, and in the evening, in summer, if the weather is very warm, a piece of ice can be added to the water.

This daily process of propagating the "startoline" was performed in the cheese factory during the year 1911 by Mr. A. T. Bruhn, with entire success, carrying along the same culture of bacteria throughout the year. Each day after inoculating the fresh bottles of milk, the remainder is examined by pouring out a little in a teaspoon or cup, to be tasted and smelled to see that it is in good condition;[1] and if so, the remainder in the jar is used in making up starter for the next day's cheese vat in the following manner:

To prepare starter from this "startoline," place in a shotgun can about eight or nine pounds of milk for each thousand received daily, cover up, and heat in a tub or deep pail of water by passing steam until the water is boiling and a thermometer in the milk reads at least 180°. Keep it at this temperature for three-quarters of an hour and then cool by filling the tub with cold water. A dash stirrer whose handle is slipped through the smallest possible hole cut in the cover is a convenience and saves opening the can for stirring. When thoroughly cool—about 70°—add to the contents of the can the remaining contents of the "startoline" jar, as stated above. Stir this well and leave for five or six hours at this temperature, after which it may be put in a cooler place to stand overnight.

The general principle on which the temperature of starters, etc., is regulated is that the starter should ripen only fast enough so as to be barely thick, or just getting thick, when required for use next day. If the acidity increases too rapidly at first, the bacteria are kept too long before use in a highly acid medium, not favorable to their growth, and in general this is to be avoided. The thickening of the milk at about 60° or 70° may be taken as an indication that the acidity is in the neighborhood of six-tenths per cent, which is about as high as it ought to go for this purpose.

To control the temperature for ripening is not so likely to be troublesome as to avoid getting dirt and foreign bacteria into the "startoline" or starter after it has been once thoroughly sterilized.

[1] To test further the quality of the starter, a bottle of the thickened milk, unshaken and unopened, may be set away in a warm place for a day or two, to see if gas bubbles or unpleasant flavors develop.

Strictly speaking it is impossible to sterilize milk so perfectly as to kill all spores by one such heating, and on this account attention should be given to selecting the best possible milk for starter making.

At the beginning of the season a small bottle of bacterial starter can be obtained from dealers or from a college of agriculture.

It is well to begin propagating the starter several days before cheese making is to begin, and also to carry along two or more starters from different sources, separately, in order that if one is lost or found unsuitable another may be at hand.

METHOD OF MAKING CHEESE BY THE NEW PROCESS.

GENERAL ARRANGEMENT OF SCHEDULE.

In making cheese by the new method the cheese maker is relieved of a great deal of the uncertainty which attends cheese making by the ordinary methods. Having inspected the milk at the intake and rejected any that is curdled or otherwise unfit for use, he determines by means of Manns's acid test the acidity of the entire vatful of mixed milk. This may be anywhere from 0.14 to 0.25 per cent, or even a little higher, but if much above 0.28 per cent the milk is likely to curdle and clog the pasteurizer. He then runs the milk through the pasteurizer and adds to the cold milk as it flows into the cheese vat enough dilute hydrochloric acid to raise the acidity of the whole vat to just 0.25 per cent (calculated as lactic acid). Three-quarters per cent of a first-class starter is added, and after heating to 85° the color and rennet are stirred in immediately.

The rest of the process is conducted according to a fixed time schedule, which is never varied. The time from adding rennet to hooping the curd is always exactly five hours and fifteen minutes, and the intermediate process is as shown in Table 18. This is carried on every day in the season without exception.

While it may be found desirable or convenient at some factories to modify somewhat this routine, described below, yet it appears practically certain that whatever routine of operations is adopted at any factory, it can be followed without modification throughout the season.

TABLE 18.—*Time schedule for making cheese by the new method.*

Operation.	Time interval between operations.		Total time after adding rennet.	
	H.	*m.*	*H.*	*m.*
Adding rennet	0	0	0	0
Cutting the curd	0	25	0	25
Beginning to heat	0	15	0	40
Turning off steam	0	20	0	60
Placing rack after drawing whey	1	25	2	25
Milling the curd	1	30	3	55
Salting the curd	1	00	4	55
Hooping the curd	0	20	5	15

For example, if the rennet were added to the milk at exactly 9 o'clock the curd would be ready to put in the hoops five hours and fifteen minutes later, i. e., at 2.15 in the afternoon. As soon as the rennet is added it is best to have a written schedule showing the time when each operation should be performed. Having once learned how to perform each operation in this method of cheese making it is only necessary to do everything in as uniform manner as possible in order to get satisfactory results daily throughout the season. There is never any need to hurry the process if the milk was overripe at the beginning, because the lactic-acid bacteria are practically all killed by the pasteurization. The same is also true of the gas-forming bacteria, so there is no time lost in working gas out of the curd. There is no reason for waiting to ripen the milk at the beginning of the process before adding rennet.

UNIFORM PROPORTION OF COLOR USED IN 1911, AND RENNET REQUIRED.

Color.—Throughout the season of 1911 two-thirds of an ounce of a standard make of cheese color per thousand pounds of milk was used, giving the cheese a medium shade of color. These cheeses were shipped into a number of different cities and appeared satisfactory to dealers in all parts of the country, except in Philadelphia, Pa., and Boston, Mass., where some dealers asked for white and others for highly colored cheese, as is shown by the following extracts from letters. Where more than one extract appears from the same city they are from different dealers.

Boston, Mass	Our market uses white cheese exclusively.
Boston, Mass	Use both white and colored.
Boston, Mass	A very light color would not do for this market.
Chicago, Ill	No comment on color.
Fond du Lac, Wis	A little too light color.
Geneva, N. Y	No comment on color.
Marshfield, Wis	No comment on color.
Minneapolis, Minn	No comment on color.
New York, N. Y	Color is exactly right.
New York, N. Y	Should be a trifle higher color.
Philadelphia, Pa	Have to have white cheese for Philadelphia.
Plymouth, Wis	No comment on color.
Sheboygan, Wis	A good commercial color, but might stand a trifle more color.
Sheboygan, Wis	No comment on color.
St. Louis, Mo	No comment on color.
Washington, D. C	Most of our customers want it colored.
Waterloo, Wis	No comment on color.

Rennet.—The same proportion of rennet is always used in this process, because the milk is always in the same condition as to acidity at the time of adding rennet, and always ripens equally fast afterwards. Therefore, having once selected the most suitable proportion of rennet, there is no reason for changing it. The use of 2 ounces of

Hansen's or Marschall's rennet per thousand pounds of milk is adopted as the best practice, since this quantity produces visible coagulation in 7 minutes, as shown in Table 2, and the curd is in prime condition for cutting in 25 minutes after adding rennet. If the rennet extract is weaker than it should be, such amounts should be used as will cause coagulation in the time stated.

If a larger proportion of rennet than 2 ounces per thousand pounds were used, there would hardly be time for the milk to become quiet before visible thickening began, and the curd might be damaged and broken through thickening while still in motion. On the other hand, over two years' experience with the method has shown that there is no need for using a smaller proportion of rennet than 2 ounces. Good cheese can be made with 1 ounce of rennet per thousand pounds of milk, but the coagulation of the milk is unnecessarily slow.

As in regular cheese making, great care must be taken not to measure or dilute rennet extract in any container in which there is present the least trace of cheese color, because the cheese color is strongly alkaline, and rennet loses its coagulating power almost instantly when in contact with alkalies.

ADDING STARTER, COLOR, AND RENNET TO THE MILK.

The temperature of all the mixed milk after pasteurizing is never above 85° and commonly only 70° to 80°. The acidity may be tested, if desired, and should be just 0.25 per cent, or between 0.24 and 0.26 per cent. Three-quarters of a pound of starter per hundredweight of milk in the vat is added immediately through a hair sieve, stirring the milk. The rake is then put in and the vat stirred, while heating up to 85°. The desired amount of color is stirred in, and always, without exception, the rennet is stirred in last of all. The rennet extract measured out for 5,000 pounds of milk should be diluted in a pailful of water. In adding rennet, first stir the milk across the vat the short way, going rapidly from one end of the vat to the other. With the largest-sized vats, two men with rakes may begin at the middle and walk toward the ends while stirring. Then walk back along the vat, adding the diluted rennet from a pail to the milk which is still in vigorous motion, noting on the clock the instant when the rennet first enters the milk. Set down the pail and again stir the milk across the vat the short way, with the rake or rakes, for exactly one minute, in which time the operator should be able to walk up and down the vat three or four times. In this way the smallest as well as the largest vats of milk should be set. Take out the rakes promptly one minute after the rennet entered. Cover the vat at once, and leave undisturbed. No top stirring is necessary or permissible, as the milk begins to thicken almost exactly seven min-

utes after adding rennet, before there is any visible cream rising. Follow exactly the directions as to temperature, acidity, and proportion of rennet every day in the season.

CUTTING, STIRRING, AND HEATING THE CURD.

The curd formed in this process is always ready to cut exactly 25 minutes after the rennet entered the milk. Therefore as soon as the rennet has been added it is best for the operator to write the entire time schedule, as shown in Table 18, for the rest of the day's work on a paper, or, better, on a blackboard, which can be seen across the room. Some operators may suppose that possibly the curd might be cut a little earlier or later, but experience has shown that the curd is always in a thoroughly satisfactory condition for cutting just 25 minutes after adding rennet. There is therefore no need for repeated testing of the curd with the finger; it is only necessary to keep an eye on the clock, and follow the time schedule.

In cutting, begin with the horizontal knife and cut lengthwise of the vat; then use the vertical knife across the vat, cutting alternately toward and away from the operator. Finally cut lengthwise, with the vertical knife. Do not cut the vat more than once in each direction, and try to do the cutting in exactly the same manner every day. The different cuts should not lap, nor should portions of the curd wider than three-eighths of an inch be left uncut between the knives, except in the following case: In cutting next to the sides of the vat, as in the first and last cuts in each direction, hold the knife as close to the metal sides of the vat as possible. If the knife does not appear wide enough to cut the remaining curd at the last stroke, cut close to the tin and leave a narrow strip of uncut curd, not at the edge of the vat, but between the last cut and the next to the last. This strip will be cut more thoroughly by the knives moving in other directions than if it had been left next the tin. Knives with blades three-eighths of an inch apart are required for this method.

Immediately after cutting put the agitator blades in place and start them in motion. The curd obtained in this process is so firm and solid that this can always be done safely. Go around the vat with the hand some time during the next 15 minutes, loosening the curd from the sides, bottom, and corners of the vat. A form of agitator which is very satisfactory has one pair of revolving blades which also move up and down the vat, somewhat resembling the motion of the rake.

Exactly 15 minutes after cutting turn steam into the jacket of the vat, and raise the temperature gradually during the next 20 minutes—just 19° to 104°—which temperature is maintained until the whey is drawn.

A UNIFORM LAYER OF CURD, SHOWING USE OF CURD GAUGE.

DRAWING THE WHEY, MATTING, CUTTING, AND TURNING THE CURD.

The agitator is left running until about two minutes before the whey is to be drawn, when it is removed, and the curd, after settling a few seconds, is pushed slowly away from the gate with one or two rakes. The whey strainer is placed inside the vat and the hair sieve below the gate in the conductor, the gate being opened at such a time as will permit the whey to be out and the first rack to be put in place at the time given in the schedule. When the whey is nearly all out, the gate end of the vat is lowered gradually, and a few seconds later the curd is pushed down toward the gate, leaving the upper third or half of the vat bottom bare and free from whey. In this process the curd is always sufficiently firmed in the whey so as not to need any stirring in the whey or on the rack. With reasonably brisk work the curd can be transferred to the curd cloth on the rack with a curd pail or scoop before it has time to become lumpy on the bottom of the vat. Each pail of curd as it strikes the rack should fall apart loosely and not show the presence of great lumps of curd matted together. Any such lumps should be lightly broken up with the hand, and if many lumps appear it indicates lack of skill and quickness.

The curd is piled evenly on the rack about 4 or 5 inches thick, and the top is leveled off with the hand in the usual manner and covered with a curd cloth. More racks if necessary are put in place and the vat is finally covered, leaving the curd to drain. The little curd gauge, made of wood, devised during the course of these experiments is a help in getting the layer of curd of the right thickness and also gives a good square end to the curd, which makes it easier to cut into blocks of uniform shape. (See Pl. VI.)

Just 15 minutes after the time scheduled for putting in the rack the curd gauge is removed and the cutting of the matted curd into blocks 8 inches square, or 6 by 12 inches, is begun.

The blocks are turned over immediately after cutting, and again turned 15 minutes later. They are then turned once in 10 minutes, and one hour after drawing the whey are piled two deep, and repiled every 10 minutes until milled. In turning and piling, care is always used to turn the outer cooler surfaces toward the inside, in order that the entire mass of curd may remain at practically uniform temperature throughout, as in ordinary practice.

MILLING, SALTING, AND HOOPING THE CURD.

Exactly one and a half hours after the whey is drawn the curd is milled. The milled curd is piled along the sides of the vat, so as to drain toward the middle. It is stirred up with the hands from the bottom, turning the pile over about once every 10 minutes after milling, so as to cool it somewhat, prevent matting, and allow free

drainage. Little or no white whey ever escapes from the curd after milling or salting when made up by this process, although some clear whey or brine does drain away.

One hour after milling salt is thoroughly mixed with the curd at the rate of 2 pounds of salt per hundred of curd, which amounts practically to 2 pounds per thousand of milk in the spring and early summer, and 2¼ pounds per thousand of milk in the fall, when the yield of cheese per hundredweight of milk is somewhat greater. The curd is stirred over several times during the next 20 minutes, by which time the salt is all dissolved, and the curd, at a temperature of 82° to 86°, is ready to be hooped. Each hoopful of curd is covered with a cloth and follower as soon as filled, in order to prevent the surface of the curd from cooling so far that it might fail to close well in the press.

It is of the utmost importance that every cheese should be well closed and develop a perfect rind, free from cracks or other openings. Where openings occur mold is sure to enter during the curing process, and the flavor especially is apt to suffer as a result.

PRESSING AND DRESSING THE CHEESE.

Throughout the present set of experiments the cheese has been pressed for about an hour, applying pressure with the hand lever only, and at first only sufficient pressure is used to keep the drippings running from the hoops. After an hour the cheese is dressed and returned to the press, when continuous pressure is put on and it is left for the night.

In bandaging the hoops, the usual starched circles are used under the heavy muslin or duck cap cloths, or if it is found that the circles are hard to remove for paraffining they may be left out and the cap cloths left on the cheese until paraffined. The cap cloths, being of heavy cloth, can be stripped off rapidly without tearing and washed; in this way they may be used many times. The next morning it is customary, as in cheese factories generally, to look over the cheese, straighten any bandages which may be faulty, and turn any crooked cheese over in the press, leaving them until noon to straighten.

DRYING, PARAFFINING, AND CURING.

The cheeses when taken from the press are stenciled with the brand and date of making or a reference number, and placed on shelves in a well-ventilated room to dry on the surface. This room may be as high as 70°. Here they are turned over once a day.

The cheese should be paraffined when 5 to 10 days old, or possibly earlier. The paraffin should be at 220° F., at least, and better at

230° to 250° F. The thinnest possible coat of paraffin is the best, and the cheese should be held in the paraffin about 5 seconds and then drawn out and left to drain over the vat, on a rack, until it can be handled. A thin coating of paraffin is flexible and less likely to crack than a thick coating.

It is possible to cure this cheese at any temperature between 34° and 75°. When it is desirable to cure the cheese as fast as possible, a temperature of 75° may be used without injury to the quality. However, at this temperature there is considerable shrinkage, and it is necessary to wipe the cheeses occasionally and turn them over to prevent them from getting moldy and sticking to the shelves.

At 45° to 55° the cheese cures well, with little shrinkage and a minimum amount of labor. It also cures well when stored at 34° at the age of 1 week and develops little or no mold on the surface, but owing to the extra cost this temperature should only be employed where it is necessary to hold the cheese for a considerable length of time.

BRANDING AND SELLING THE CHEESE.

In order that customers may be sure that they are getting genuine pasteurized-milk cheese when called for, every cheese should be marked with the words "Pasteurized cheese" running all round the edge of the cheese. All persons making cheese according to the process here described should use such a brand, in order to distinguish this product from the ordinary Cheddar cheese. A large number can be rapidly marked with a rubber stamp or by rolling the cheese over rubber type, set in a board, as shown in figure 2. Narrow strips of wood on each side of the board prevent the cheese from rolling sidewise off the type.

In a new style of product uniformity is a quality which consumers and dealers require. It is recommended that the maker of this style of cheese keep back one cheese from each day's make, when shipping, until the consignment has been accepted and paid for by the buyer. The sample cheese can then be sent along with the next shipment without plugging. If necessary, the cheese can be plugged with a trier, and by this means the maker will be able to study any faults which may be observed by the buyer and avoid them in the future. Names of leading cheese dealers who have already received sample shipments of this make of cheese and found it suitable for their trade may be obtained from the authors.

Where a maker doubts whether the buyer is giving him fair treatment, it is recommended that parts of each day's make be sent to two different dealers, whose criticisms, if any are received, can be compared by the maker at the factory.

TESTING CHEESE FOR MOISTURE WHEN DRESSED IN THE HOOP.

In making cheese by this process, the green cheese was found to differ very little in moisture content from day to day, as is shown in Table 19. Excepting the first day the cheese was made each day in two vats, and each vat of curd was tested for moisture separately.

The determination of moisture in cheese is not recommended as a part of the daily work in a factory. It is of great value, however, in experimental work, where it is desired to study the effect on their moisture content of different methods of handling curds, or the effect of different moisture content on the market value or keeping quality of cheese.

FIG. 2.—Method of marking cheese.

Moisture tests are easily made. It is objectionable, however, to plug a new cheese every day for a moisture test because of the danger of admitting molds, etc., beneath the rind, and it has been found that plugging the green cheese can be entirely avoided by sampling it at the time it is dressed in the hoop, about one hour after putting it to press. The trier hole made at this time by turning down the bandage and inserting the trier at the side will close entirely over night in the press, leaving the rind perfect. Samples of cheese thus taken from the dressed curd and tested for moisture agreed closely in moisture content with samples taken with a trier from the same cheese the next day, after pressing about twenty hours, as may be seen from Table 19.

The moisture tests were all made by heating 10-gram portions of the curd for at least three hours in the Wisconsin high-pressure

steam oven.[1] After three or four hours there is practically no further loss of weight from samples of fresh curd in 24 hours' heating. Samples of cured cheese continue to lose weight with continued heating much more noticeably than samples of fresh curd or green cheese.

TABLE 19.—*Comparison of moisture determinations made on samples taken when cheese was dressed, three-quarters to one hour after pressing, and on samples taken from green cheese, next day, when removed from press.*

Date.	Moisture content when cheese was dressed.			Moisture content, next day, when removed from press.			Difference.
	First.	Second.	Average.	First.	Second.	Average.	
1911.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Aug. 15	37.60	37.40	37.50	37.95	37.25	37.60	+0.10
16	38.50	38.70	38.60	38.50	39.00	38.75	+ .15
16	38.50	38.90	38.70	38.05	38.50	38.27	− .43
17	39.60	39.10	39.35	38.50	38.60	38.55	− .80
17	38.90	39.00	38.95	39.40	39.40	39.40	+ .45
18	37.80	37.75	37.77	37.75	37.95	37.85	+ .08
18	42.25	42.25	42.25	41.25	41.40	41.32	− .93
23	38.80	38.80	38.80	38.05	38.45	38.25	− .55
23	42.25	42.45	42.35	42.20	42.10	42.15	− .20
24	39.35	39.05	39.20	39.70	40.30	40.00	+ .80
24	44.25	44.30	44.27	43.15	43.30	43.22	−1.05
25	39.55	39.70	39.62	39.30	39.65	39.46	− .16
25	44.10	44.45	44.27	44.25	44.95	44.60	+ .33
26	38.95	39.10	39.02	38.80	39.00	38.90	− .12
26	44.30	44.60	44.45	42.80	43.00	42.90	−1.55

RESULTS OF TWO YEARS' TRIAL OF THE METHOD.

INCREASED YIELD OF CHEESE OBTAINED BY THE NEW PROCESS.

APPARATUS AND METHODS OF STUDY.

In the season 1909–1910 it was found that an increased weight of cheese is regularly obtained after pasteurization as compared with the weight obtained by the regular factory methods. For the purpose of accurately studying the yield of cheese in 1911 two scales were used, one of 5,000 pounds' capacity graduated on the beam to one-half pound and one of 300 pounds' capacity graduated on the beam to one-tenth pound. The larger scale was set up permanently in one corner of the make room, and a wooden frame carrying a 300-gallon steel receiving vat was placed upon it. The outlet of the vat is of sanitary metal piping, suspended by wire to the vat in such a way that the pipe and contents are weighed each time with the vat. The frame, vat, and pipe weighed 487½ pounds when empty. The separate weights and the scale on the beam were carefully tested by use of test weights. The entire set of weights agreed among themselves so closely that no difference could be detected in the equilibrium of the beam when one weight was substituted for another in weighing a load. The error in a single weighing is not over one-quarter of a

[1] Farrington, E. H. A creamery method for the determination of water in butter. Wisconsin Agricultural Experiment Station, Bulletin 154. Madison, Sept., 1907.

pound with large or small loads. Except when weighing the lever is kept up, thus relieving the knife edges from load and wear.

The method of using this apparatus is as follows: The vat being empty with the pipes in place and stopcocks closed, the supply of milk is run into the vat through a conductor and cloth strainer. The strainer and conductor are then removed, the lever is lowered, and the weight of vat and contents determined. It is our habit to balance the scales exactly, giving neither "up" nor "down" weight. The lever is then raised, and the operator climbs up the ladder on the frame to the runboard along the side of the vat. With a dipper he stirs the milk continuously and vigorously for 5 or 10 minutes, and continues stirring while a portion of the milk is being drawn out for use in one of the experimental cheese vats. The vat and the remaining milk are then weighed with the same precautions as before, after which another portion of the milk may be drawn off for use in another vat in the same manner.

The precautions mentioned above seemed sufficient to insure that the milk used in the two vats—one for ordinary and one for pasteurized cheese—was thoroughly mixed at the time it was drawn from the receiving vat, and that each lot was weighed accurately with a total possible error of not over one-half a pound in a vat of 200 to 2,000 pounds of milk—an error of one-fortieth to one-fourth of 1 per cent, at most.

The other new scale mentioned above is a counter scale graduated on the beam to one-tenth of a pound and sensitive to one-twentieth of a pound with any load up to 200 pounds. This was used for weighing the cheese throughout the work here described. The set of weights used with this scale agreed among themselves and with the test weights mentioned above in the description of the other scale.

With the smaller scale, 20 to 200 pounds of cheese could readily be weighed with an error of not over 0.05 of a pound, or 0.25 per cent, at most. On 68 days during the season of 1911 the receiving vat of milk was divided into two accurately weighed portions for this experiment. One of these was pasteurized and made up into cheese by the new method, the other portion was made up into cheese by regular factory methods. The cheese was 13½ inches in diameter by 4 inches high, the "daisy" size. The green cheese was always weighed as quickly as possible after being removed from the hoops. The daily record of weights of milk used and of cheese obtained, and the per cent of increased yield which resulted from pasteurization, are shown in Table 20.

TABLE 20.—*Increased yield of green cheese obtained by the new method from pasteurized milk.*

Date made.	Pasteurized milk.			Raw milk.			Gain by pasteurized milk.	Proportion of starter used.	
	Milk used.	Green cheese.	Yield of cheese per hundredweight of milk.	Milk used.	Green cheese.	Yield of cheese per hundredweight of milk.		Pasteurized.	Raw.
1911.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per ct.*	*Per ct.*
Feb. 23	538.0	53.20	9.89	380.0	35.40	9.31	6.23	0.75	0.00
24	504.5	51.00	10.11	380.0	36.60	9.63	4.98	.75	.00
27	1,026.5	106.20	10.35	600.0	57.80	9.63	7.48	.75	.00
28	800.0	82.20	10.27	400.0	38.30	9.57	7.31	.75	.75
Mar. 1	350.0	35.40	10.11	510.0	50.20	9.84	2.75	.75	1.50
2	389.5	39.00	10.01	628.0	59.70	9.51	6.61	.75	.75
3	340.0	35.00	10.29	522.0	52.30	10.02	2.79	.75	1.50
7	855.0	88.20	10.32	380.0	38.40	10.11	2.08	.75	2.00
8	590.0	60.70	10.29	388.5	39.30	10.12	1.68	.75	1.50
9	418.0	42.80	10.24	417.5	41.00	9.82	4.27	.75	1.00
10	442.0	44.70	10.11	700.0	66.40	9.49	6.53	.75	.00
13	1,166.0	122.00	10.46	275.0	25.70	9.34	12.00	.75	.00
14	956.0	103.40	10.81	260.0	25.80	9.92	8.97	.75	.75
15	570.5	58.10	10.18	380.0	37.50	9.87	3.14	.75	.75
16	531.5	56.90	10.71	359.0	37.40	10.42	2.78	.75	2.00
17	395.0	41.20	10.43	396.0	39.80	10.05	3.78	.75	2.50
20	1,344.0	136.00	10.12	384.0	36.60	9.53	6.19	.75	.00
21	570.0	56.40	9.89	378.0	35.30	9.34	5.89	.75	.00
22	362.5	36.00	9.93	542.0	51.80	9.56	3.87	.75	1.67
Apr. 5	585.0	60.80	10.39	390.0	37.70	9.67	7.45	.75	.75
7	508.0	51.15	10.07	339.5	32.50	9.57	5.22	.75	.75
11	549.0	55.00	10.02	549.0	52.60	9.58	4.59	.75	.75
13	364.0	35.70	9.81	364.0	34.55	9.49	3.37	.75	.75
17	800.0	80.25	10.03	600.0	55.50	9.25	8.43	.75	.00
18	720.0	71.15	9.88	540.0	49.80	9.22	7.16	.75	.00
24	1,254.0	122.80	9.79	660.0	61.90	9.38	4.37	.75	.75
27	570.0	55.30	9.70	380.0	35.70	9.39	3.30	.75	.75
28	420.0	40.85	9.73	420.0	40.05	9.54	1.99	.75	.75
May 2	636.0	65.05	10.23	424.0	42.00	9.91	3.23	.75	.75
3	558.0	54.30	9.73	372.0	35.55	9.56	1.81	.75	.75
8	1,693.0	158.15	9.34	800.0	70.95	8.87	5.30	.75	.75
10	798.0	77.60	9.72	798.0	73.70	9.24	5.19	.75	.75
15	1,587.0	161.60	10.18	800.0	76.90	9.61	5.93	.75	.75
17	1,088.5	109.00	10.01	800.0	76.60	9.57	4.60	.75	.75
22	1,223.0	129.40	10.58	800.0	78.20	9.77	8.29	.75	.75
25	851.0	87.00	10.22	800.0	78.80	9.85	3.76	.75	.75
29	1,315.0	138.60	10.54	800.0	80.20	10.02	5.29	.75	.75
June 1	798.0	83.50	10.46	800.0	83.10	10.39	.67	.75	.75
2	799.5	82.85	10.36	800.0	79.50	9.94	4.23	.75	.75
7	790.5	79.65	10.07	800.0	76.60	9.57	5.22	.75	.75
9	800.0	82.30	10.29	800.0	78.15	9.77	5.32	.75	.75
13	1,090.0	119.70	10.98	800.0	80.20	10.02	9.58	.75	.00
15	795.0	85.50	10.75	800.0	80.70	10.09	6.54	.75	.75
16	800.0	83.45	10.43	800.0	78.95	9.87	5.67	.75	.75
19	810.0	87.60	10.81	800.0	79.65	9.96	8.54	.75	.00
21	798.5	81.75	10.24	800.0	77.70	9.71	5.46	.75	.75
26	770.0	80.65	10.47	770.0	75.45	9.80	6.84	.75	.00
27	801.0	83.50	10.42	800.0	79.00	9.88	5.46	.75	.75
28	801.5	85.90	10.73	800.0	82.00	10.25	4.68	.75	.75
July 3	1,234.0	122.75	9.95	800.0	72.35	9.04	10.07	.75	.00
6	995.0	102.45	10.30	660.0	66.10	10.02	2.79	.75	.75
8	1,068.0	108.50	10.16	660.0	62.80	9.52	6.72	.75	.00
10	1,064.5	107.30	10.08	800.0	74.35	9.29	8.50	.75	.00
11	914.0	93.50	10.23	660.0	63.65	9.64	6.12	.75	.00
12	873.0	93.15	10.67	800.0	78.20	9.77	9.21	.75	.75
24	1,195.0	125.10	10.47	600.0	58.20	9.70	7.94	.75	.75
26	1,099.0	118.32	10.77	190.0	19.32	0.17	5.90	.75	.00
Aug. 29	294.5	31.58	10.72	290.0	30.50	10.52	1.90	.75	.75
30	344.0	35.82	10.41	340.0	34.05	10.01	4.00	.75	.75
Sept. 1	322.0	34.10	10.59	320.0	32.60	10.19	3.92	.75	.75
5	291.5	31.00	10.63	292.0	29.65	10.15	4.73	.75	.75
6	276.0	28.95	10.49	275.0	27.20	9.89	6.46	.75	.75
7	286.5	31.03	10.83	286.5	29.48	10.29	5.24	.75	.75
8	292.0	31.50	10.79	292.0	30.25	10.36	4.14	.75	.75
20	263.0	29.15	11.08	263.0	27.80	10.57	4.82	.75	.75
22	265.0	29.20	11.02	266.5	28.05	10.52	4.75	.75	.75
25	748.0	83.90	11.22	250.0	26.40	10.56	6.25	.75	.75
Oct. 2	700.5	79.25	11.31	420.0	45.10	10.74	5.31	.75	.75
3	251.0	27.75	11.05	250.0	26.25	10.50	5.24	.75	.75
Average..	....	....	10. 7	....	....	9.815	5.374	....	....

It will be noted that every day in the season there was a greater yield of cheese from the pasteurized milk. From 250 to 1,700 pounds of milk were handled in each vat. The average yield of green cheese from raw milk was 9.815 pounds and from pasteurized milk 10.337 pounds per hundred pounds of milk.

The daily increase in yield ranged from 0.6 per cent to 12 per cent, and in 50 cases (72 per cent) lay between 3 and 8 per cent, while the average increase in yield by the new process on 69 days was 5.37 per cent.[1] On 45 days the same proportion of skim milk starter—three-fourths per cent—was used in both the raw and the pasteurized milk. In the raw milk none was used on 16 days, and on 8 days 1 to 2½ per cent (on the average 1.71 per cent) was used, while in every case the pasteurized milk received three-fourths per cent starter. If the use of starter affects the yield of cheese, the average yield from the pasteurized milk on 16 days was raised about three-fourths per cent, while the average yield from raw milk was raised on 8 days about 1.71 per cent. These two effects offset each other in the table, giving a slight advantage to the yield from the raw milk, so that the final average figure—5.37 per cent—representing the average gain in yield of green cheese by the new process, is no higher and possibly a trifle lower than it would have been if equal proportions of starter had been used in all cases.

Among the 17 cases in Table 20 in which no starter was used in the raw-milk vat, the average gain in the pasteurized-milk vat, using three-fourths per cent starter, was 7.48 per cent; and in 8 cases where more than three-fourths per cent starter was used in the raw milk, the average gain in yield in the pasteurized-milk vat was 3 per cent. From this it would appear that the proportion of starter used does notably affect the yield of cheese, contrary to some recent statements.[2]

SEARCH FOR SYSTEMATIC ERRORS IN EXPERIMENTS ON YIELD OF CHEESE.

The presence of systematic errors was carefully guarded against in the daily work on the yield of cheese. Before dividing the milk from the receiving vat for use in the two make vats, the milk was first thoroughly stirred for 4 to 10 minutes, as already stated, and the stirring was continued while the milk was running out. The portion of milk drawn out first was commonly used for making the raw-milk cheese, but sometimes, as on March 8, 9, 10, 17, 21, 22, and April 7, 11, 17, 18, and May 10, the portion drawn first was used for making the past urized-milk cheese. The average gain in yield through pas-

[1] Both the median and the mode lie between 5 and 6 per cent. The mode is the class which occurs with the greatest frequency; the median is the magnitude at the middle of the series from largest to smallest. See "Statistical Methods," by C. B. Davenport, New York, 1899, or "Principles of Breeding," by E. Davenport, Boston, 1907, p. 684.

[2] Van Slyke, Lucius L., and Publow, Charles A. The science and practice of cheese making. New York, 1909. See p. 69.

teurization on these 11 days was 5.15 per cent, so nearly equal to the general average of 5.37 per cent (see Table 20) as to indicate that the gain in yield is not due to any difference in composition of the milk when divided into two lots. Carefully tested thermometers and the same pair of curd knives were used in every vat.

Usually the vat of pasteurized milk was set first with rennet, and the vat of raw milk 5 minutes later. The two vats were placed near each other, and conditions were such that one operator could stir them both at once, if desired. On 11 days, April 18, 24, 27, May 8, 10, 15, 17, August 29, 30, September 1, and October 2, the rennet was added to the raw milk first, and to the pasteurized milk 5 minutes later. The average gain in yield on the 11 days was 4.63 per cent, indicating that the order of setting the vats had nothing to do with the gain in yield.

In order to ascertain what per cent of unavoidable error enters into the measurement of yield of cheese, a special experiment was performed on 34 days. Each day, with all of the usual precautions, two lots of milk drawn from the receiving vat were run through the pasteurizer, one after the other, and made up into cheese in separate vats marked (C) and (D) standing near each other, and handled by the same operator (Mr. Bruhn). The vats were heated and set exactly 5 minutes apart by the watch, and the time schedule for each vat was strictly followed in every detail. The same curd knives and thermometer were used in both vats.

The pasteurizer and cooler are always rinsed with hot water at the beginning of the first run, but are wet with adhering milk at the close of the run just before beginning the second run. Thus the actual weight of milk in the first vat might be slightly less than it should be. To avoid this source of error, the pasteurizer and cooler were allowed to drain each time into the vat for several minutes (until the stream of milk broke into single drops), and then the metal surfaces were carefully rinsed with two measured portions of clean water. Thus the surfaces of the pasteurizer and cooler were wet with water at the beginning of the second run as well as the first. The milk content of the rinsings (see Table 21) was found to be very small and uniform, amounting to about 0.8 of a pound of milk each time, which if it were all lost from one vat but not the other would cause a difference of yield of cheese from a 500-pound lot of milk (as in Table 22) of about 0.16 per cent. In order to avoid this source of error entirely, the rinsings from both runs were either thrown away, as on the first 15 days listed in Table 22, or the rinsings after each run were added to the respective vats, as on the last 19 days.

TABLE 21.—*Milk content of rinsings of pasteurizer and cooler.*

Date.	Weight of rinsings.	Fat content.		Estimated weight of cheese in rinsings.	Estimated weight of milk in rinsings.
		Per cent.	Weight.		
1911.	*Pounds.*		*Pounds.*	*Pounds.*	*Pounds.*
Apr. 25 (Vat C)......	2.25	1.25	0.028	0.08	0.8
25 (Vat D)......	2.25	1.25	.028	.08	.8
26 (Vat C)......	2.25	1.20	.027	.08	.8
26 (Vat D)......	2.25	1.20	.027	.08	.8

The yield of cheese obtained in duplicate vats thus handled was never exactly equal and varied on the average for 33 days by 0.585 per cent of the weight of the cheese, as shown in Table 22. The milk in Vat C was drawn first from the receiving vat, and was pasteurized and set first in all cases except where otherwise noted.

TABLE 22.—*Variation in yield of cheese from duplicate vats of pasteurized milk.*

Date.	Vat C.			Ratio of milk weights.		Vat D.			Difference in yield of the two vats.
	Weight of milk used.	Weight of green cheese.	Cheese per cwt. of milk.	*Vat C.*	*Vat D.*	Weight of milk used.	Weight of green cheese.	Cheese per cwt. of milk.	
1911	*Pounds.*	*Pounds.*	*Pounds.*			*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
Mar. 23	430.0	42.50	9.884	1	1	430.0	42.55	9.895	0.11
24	390.0	38.80	9.949	1	1	390.0	39.10	10.026	.77
27	375.0	36.10	9.627	1	3	1,125.0	109.20	9.707	.83
28	350.0	36.60	10.457	1	2½	875.0	92.20	10.537	.76
29	585.0	59.10	10.102	1½	1	390.0	39.45	10.115	.13
30	495.0	50.10	10.121	1½	1	330.0	33.50	10.151	.30
31	540.0	54.20	10.038	1½	1	360.0	36.15	10.042	.04
Apr. 4	585.0	60.50	10.342	1½	1	390.0	40.55	10.397	.53
6	534.0	54.15	10.140	1½	1	356.0	37.35	10.491	[1] 3.46
10	1,080.0	106.30	9.842	3	1	360.0	35.65	9.903	.62
12	555.0	55.70	10.036	1½	1	370.0	37.60	10.162	1.25
14	380.0	38.10	10.026	1	1	380.0	38.40	10.105	.79
19	400.0	40.30	10.075	1	1	400.0	40.60	10.150	.74
20	370.0	36.75	9.932	1	1½	555.0	55.40	9.728	.50
21	380.0	37.00	9.737	1	1½	570.0	55.45	9.728	.09
25	420.0	41.00	9.762	1	1	420.0	40.90	9.738	.25
26	370.0	36.20	9.784	1	1½	555.0	54.35	9.793	.09
May 4	420.0	42.10	10.024	1	1	420.0	42.50	10.119	.95
5	531.0	51.40	9.680	1½	1	354.0	34.35	9.703	.24
9	408.0	40.65	9.963	1	1½	612.0	60.80	9.935	.28
11	410.0	41.50	10.122	1	1	410.0	41.80	10.195	.72
12	795.0	78.25	9.843	1	1	795.0	79.50	10.000	1.59
16	800.0	80.30	10.037	1	1	800.0	80.65	10.081	.44
18	600.0	63.80	10.633	1	1	600.0	62.70	10.450	1.75
19	600.0	62.20	10.367	1	1	600.0	61.95	10.325	.41
23	600.0	64.00	10.667	1	1	600.0	63.75	10.625	.39
24	612.25	64.35	10.510	1	1	612.25	65.15	10.641	1.24
30	600.0	61.30	10.217	1	1	600.0	60.75	10.125	.91
31	600.0	62.10	10.350	1	1	600.0	62.12	10.353	.03
June 6	583.0	59.15	10.146	1	1	577.75	59.15	10.238	.91
8	600.0	61.55	10.258	1	1	600.0	61.85	10.308	.49
14	600.0	62.28	10.380	1	1	600.0	62.15	10.358	.21
17	599.5	62.71	10.460	1	1	599.5	63.11	10.527	.64
20	600.0	60.30	10.050	1	1	600.0	60.90	10.150	.99
Average..	535.22	....	10.105	....		536.37	....	10.149	[1] .585

[1] The result for Apr. 6 is omitted in computing the average because of abnormal conditions.

Among the 34 days' results obtained during the season, as shown in Table 22, the difference in yield between duplicate vats exceeded 1.75 per cent in only one case. On this day there was unusual difficulty in the work because of unexpected failure of the supply of

water for cooling, and, although the direct cause of the exceptionally high figure (3.46 per cent) can not be directly traced, it seems likely that some gross error occurred, which was avoided on the other days. Therefore this figure (for April 6) is omitted from the general average.

On 28 days (82 per cent of all cases) the variation in yield between duplicate vats lay below 1 per cent and on 33 days (omitting April 6) it averaged 0.584 per cent. For present purposes, therefore, it may be considered that the figure 5.37 per cent, from Table 20, representing the average increased yield of green cheese obtained through pasteurization, is correct within 0.58 per cent, or about one-ninth of its value.

The yield of cheese from pasteurized milk is thus capable of measurement with an average difference between duplicate determinations of 0.6 per cent of the amount determined. This degree of accuracy in manipulation is comparable with that attained in many analytical chemical processes, in which a limit of 1 per cent of the amount determined is commonly set as the maximum allowable difference between duplicates.

The principal cause for the difference of 0.60 per cent in the yield in making duplicate vats of cheese does not lie in the weighing of the milk or cheese, because with the scales employed both the milk used and the cheese obtained therefrom could be weighed with an error of not over 0.10 per cent. The per cent of difference in yield was not reduced when the weight of milk handled was increased. It appears likely, therefore, that there are small unavoidable differences caused by the size of the cubes or in the manipulation of the milk and curd which cause an average difference in yield of from 0.50 to 0.60 per cent between duplicate vats.

An effort was made so far as time permitted to determine whether any one of several causes was regularly or chiefly responsible for this average difference in the yield. The stirring of the vats was done by hand in all cases where the weight of milk in a vat was less than 400 pounds. For experiments with 400 to 800 pounds of milk in a vat a pair of vats of 800 pounds capacity was used. These were stirred with a pair of wooden rakes, exactly alike in shape and size. Larger quantities of milk than 800 pounds were always handled in a vat of 2,400 pounds capacity in which a two-bladed rotating and oscillating agitator was used instead of the rake. The difference in yield between duplicate vats could not be traced to the methods of stirring. Thus, on March 27, the agitator-stirred vat (D) gave 0.83 per cent greater yield than the hand-stirred vat (C), but on April 10 the hand-stirred vat (D) gave 0.62 per cent greater yield than the agitator-stirred vat (C). The average difference on 12 days in yield between duplicate rake-stirred vats was 0.70 per cent, and the average difference in yield between duplicate hand-stirred vats on 19 days was 0.52 per cent. The differences varied slightly whatever method of stirring was employed.

Again, handling different amounts of milk did not appear to affect the yield in duplicate vats. On 12 days, using one and one-half to three times as much milk in one vat as in the other, the average difference in yield was 0.40 per cent, which is a little smaller than the average of the other days, showing that the quantity of milk handled by this method does not affect the yield. Since the same results are obtained in a small vat with 375 pounds of milk as in a large one with 1,125 pounds of milk, it is believed that the general results of this investigation are applicable to the largest sized vats of milk used in factories.

SHRINKAGE BEFORE PARAFFINING, AND YIELD OF PARAFFINED CHEESE.

Since there is always some loss in weight of cheese previous to paraffining, it is of interest to compare the shrinkage of ordinary cheese with that of new-process cheese, and to determine whether there is an increased yield of pasteurized-milk cheese when paraffined corresponding to the increased yield observed in the same cheese when green. This can be done readily from Table 23, which shows the average results for the season and also the range of daily variation.

TABLE 23.—*Comparison of old and new process cheese as to shrinkage before paraffining and yield of paraffined cheese.*

Date made.	Age when paraffined.	Shrinkage per 100 pounds of green cheese before paraffining.		Yield per 100 pounds of milk.		Gain in yield by new process.
		Pasteurized.	Raw.	Pasteurized.	Raw.	
1911.	*Days.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
Feb. 23	19	5.92	5.23	9.30	8.83	5.32
24	18	5.98	5.05	9.50	9.14	3.94
27	15	5.32	4.67	9.79	9.18	6.64
28	14	5.23	4.57	9.74	9.14	6.56
Mar. 1	13	5.36	4.88	9.57	9.36	2.24
2	12	5.26	4.35	9.49	9.09	4.40
3	15	5.71	5.35	9.71	9.48	2.43
7	11	5.21	4.43	9.78	9.66	1.24
8	10	4.45	4.58	9.83	9.65	1.86
9	9	5.49	4.82	9.68	9.35	3.53
10	8	3.58	3.35	9.75	9.17	6.32
13	12	5.08	4.28	9.93	8.95	10.95
14	11	5.13	4.26	10.26	9.50	8.00
15	10	3.96	3.73	9.78	9.50	2.95
16	9	4.22	3.61	10.25	10.04	2.09
17	8	3.88	3.27	10.03	9.72	3.19
20	12	5.37	4.37	9.58	9.11	5.16
21	11	4.42	3.68	9.46	8.99	5.23
22	10	4.72	3.86	9.46	9.19	2.94
Apr. 5	10	4.36	3.58	9.94	9.32	6.65
7	8	4.10	3.85	9.66	9.20	4.60
11	10	5.09	4.56	9.51	9.14	4.05
13	8	4.62	4.05	9.35	9.11	2.63
17	12	5.11	4.23	9.52	8.86	7.45
18	11	4.85	4.42	9.40	8.81	6.70
24	12	5.05	4.11	9.30	8.99	3.45
27	9	3.98	3.64	9.32	9.05	2.98
28	8	2.82	2.62	9.45	9.29	1.72
May 2	11	4.36	3.93	9.79	9.52	2.84
3	10	4.33	4.08	9.31	9.17	1.53
8	13	4.52	4.65	8.91	8.46	5.32
10	11	4.19	3.73	9.32	8.89	4.83
15	12	4.64	4.36	9.71	9.19	5.65
17	10	4.57	3.98	9.49	9.19	3.26
22	12	4.71	4.09	10.08	9.37	7.57
25	11	4.71	3.93	9.74	9.46	2.96
29	13	4.72	4.37	10.04	9.59	4.69

TABLE 23.—*Comparison of old and new process cheese as to shrinkage before paraffining and yield of paraffined cheese*—Continued.

Date made.	Age when paraf-fined.	Shrinkage per 100 pounds of green cheese before paraffining.		Yield per 100 pounds of milk.		Gain in yield by new process.
		Pasteur-ized.	Raw.	Pasteur-ized.	Raw.	
1911.	*Days.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
June 1	10	3.92	3.67	10.05	10.01	0.40
2	9	4.22	3.92	9.93	9.55	3.98
7	7	4.21	3.66	9.66	9.22	4.77
9	8	3.80	3.58	9.90	9.42	5.09
13	10	5.26	4.74	10.40	9.55	8.90
15	8	4.49	3.82	10.18	9.70	4.95
16	7	4.43	3.64	9.97	9.51	4.84
19	12	4.85	4.27	10.29	9.53	7.97
21	10	4.46	4.18	9.78	9.31	5.05
26	12	4.53	4.17	10.00	9.40	6.38
27	11	4.19	3.80	9.99	9.50	5.16
28	10	4.02	3.41	10.30	9.90	4.04
July 3	14	4.56	3.91	9.49	8.69	9.21
6	11	4.20	4.01	9.86	9.61	2.60
8	9	3.64	3.42	9.79	9.19	6.53
10	10	4.80	4.64	9.60	8.86	8.35
11	11	4.46	4.01	9.77	9.26	5.51
12	10	4.54	3.65	10.19	9.42	8.17
Aug. 29	11	4.99	6.07	10.18	9.88	3.14
30	10	4.22	4.05	9.97	9.61	3.75
Sept. 1	8	4.14	4.14	10.15	9.77	3.89
5	13	4.35	4.05	10.17	9.74	4.42
6	12	3.82	3.49	10.09	9.54	5.65
7	11	3.49	2.99	10.45	9.98	4.71
8	10	3.17	2.81	10.45	10.07	3.77
20	10	3.80	3.41	10.66	10.21	4.41
22	8	3.43	3.21	10.64	10.19	4.42
25	16	6.49	5.87	10.49	9.94	5.53
Average..	....	4.546	4.078	9.833	9.388	4.761

In practically every case in Table 23 the pasteurized-milk cheese showed a greater shrinkage than the raw-milk cheese during the period before paraffining, which was 7 to 19 days. The average shrinkage of raw-milk cheese before paraffining, for all 65 cases, was 4.08 pounds per hundred of green cheese, and for the pasteurized-milk cheese it was 4.55 pounds per hundred, nearly one-eighth greater than the raw. This excess shrinkage is observed whether the cheese was paraffined at 7 or 14 days, as is shown in the following table, which is a summary of Table 23.

TABLE 24.—*Shrinkage of cheese when paraffined at different ages (summary of Table 23).*

Age when paraffined.	Cases av-eraged.	Average shrinkage in weight per 100 pounds green cheese.		Excess in pasteurized.	
		Pasteur-ized.	Raw.		
Days.	*Number.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent of raw.*
7 to 8	11	3.95	3.56	0.39	11
9	5	4.31	3.88	.43	11
10	16	4.35	3.83	.52	13
11	12	4.52	4.10	.42	11
12	10	4.84	4.17	.67	16
13 to 19	11	5.29	4.78	.51	11

On account of this excess shrinkage before paraffining, amounting to about one-half pound per hundred pounds of cheese, the average increased yield of 5.37 pounds per hundred of milk observed in the pasteurized cheese when green (Table 20) was reduced to 4.76 pounds (see Table 23) by the time the cheese was paraffined.

SHRINKAGE AND YIELD OF CURED CHEESE.

The further shrinkage and yield of cheese after paraffining was studied: (1) With cheese cured at Madison, Wis., at a temperature of 60° to 75°; (2) with cheese cured at New Orleans, La., and weighed both at New Orleans [1] and Madison; (3) with cheese cured at New Orleans or at Columbus, Ga., and weighed both at Chicago and at Madison; (4) with cheese cured in a warm room at Madison; and (5) with cheese put in cold storage at 34° F. at Waterloo, Wis., at different ages after paraffining. So far as possible duplicate cheeses from the same days' make were cured in the different ways stated.

These different methods of curing were chosen for study as representing (1) curing conditions at Wisconsin factories; (2), (3), and (4) conditions to which annually large amounts of cheese are subjected when shipped south for sale; and (5) when cured in cold storage as commonly practiced by dealers.

The shipments to New Orleans were sent on four dates between April 29 and July 24, 1911. Each shipment consisted of 9 to 25 pasteurized-milk cheeses, and an equal number of raw-milk cheeses for comparison. In order that the cheese stored might be as representative as possible, each pair represented a different day's make.

For each lot of cheese shipped away from Madison for storage, a duplicate lot from the same days' make was kept at Madison. The method of designating these different lots of cheese is shown in Table 25:

TABLE 25.—*Reference numbers to different lots of cheese stored in 1911.*

Date made.	Cheese Nos.	Cured at Madison.	Cured at New Orleans.	Cured at New Orleans and Columbus, Ga.	Cured in warm room at Madison.	Cured at Waterloo, Wis.
Feb. 23 to Apr. 16	171 to 207	1A	1B			
Apr. 24 to May 17	211 to 227	2A	2B			
May 22 to June 16	230 to 246	3A	3B	3C	3D	
June 19 to July 12	248 to 263	4A	4B	4C	4D	
July 13 to Aug. 21	264 to 283	5A				5E

In addition to weighing each cheese separately they were also weighed in lots of five, and the close agreement of the weight of a lot

[1] The details of the work at New Orleans connected with the storage, weighing, and shipping of the cheese used in this test were handled by Mr. W. J. Bleecker, junior dairyman of the Dairy Division, Bureau of Animal Industry. Thanks are due to Mr. Bleecker for his very careful attention to this work.

of five with the sum of the five separate weights proved the accuracy of the weighing. This general method of double weighing was followed in obtaining all the weights of cheese in the 14 lots.

The tabulated results show the shrinkage of the different lots and the yield of green, paraffined, and cured cheese per hundred pounds of milk. In addition to the average results for each lot of cheese, the individual variations in shrinkage and yield of the single cheeses are shown, from which the extent of daily variations from the general average figures can be studied by anyone interested.

Cheese cured at Madison (lots 1A to 5A).—Fifty-two pairs of cheese cured at 60° to 70° were weighed one or more times (92 times in all) at different ages, from 21 to 117 days after paraffining. In every case there was a gain in yield of pasteurized cheese over raw cheese. The gain averaged 4.59 per cent among 10 pairs of cheese cured 20 to 30 days, 4.58 per cent among 37 pairs of cheese cured 30 to 60 days, 4.38 per cent among 28 pairs of cheese cured 60 to 90 days, and 3.58 per cent among 17 pairs of cheese cured 90 to 117 days. On the average of all cases the gain in yield of pasteurized over raw was 4.22 per cent of the weight of the cheese.

TABLE 26.—*Comparison of yield of raw and pasteurized-milk cheese after curing for various lengths of time at Madison, Wis.*

Date made.	Time cured after paraffining.	Weight of cured cheese per 100 pounds of milk.		Gain by pasteurization.	
		Pasteurized.	Raw.		
1911.	*Days.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
Apr. 24	21	9.27	8.96	0.31	3.46
Mar. 20	26	9.52	9.06	.46	5.08
21	26	9.40	8.94	.46	5.15
22	26	9.37	9.12	.25	2.74
20	33	9.47	8.99	.48	5.34
17	32	9.87	9.63	.24	2.49
16	32	10.02	9.96	.06	.60
15	32	9.68	9.38	.30	3.20
14	32	10.03	9.34	.69	7.38
13	32	9.72	8.80	.92	10.46
2	42	9.53	9.36	.17	1.81
7	42	9.57	9.49	.08	.84
8	42	9.61	9.51	.10	1.05
9	42	9.55	9.29	.26	2.80
10	42	9.62	9.09	.53	5.83
Apr. 17	42	9.30	8.73	.57	6.54
18	42	9.13	8.64	.49	5.67
May 15	44	9.43	8.89	.54	6.07
17	44	9.15	8.85	.30	3.39
June 13	44	9.86	8.94	.92	10.29
15	44	9.70	9.30	.40	4.30
16	44	9.64	9.04	.60	6.64
Feb. 23	45	9.12	8.63	.49	5.67
24	45	9.26	8.93	.33	3.69
27	45	9.51	9.00	.51	5.67
28	45	9.49	8.99	.50	5.56
Mar. 1	45	9.57	9.08	.49	5.39
2	45	9.21	8.94	.27	3.02
Apr. 11	50	9.29	8.98	.31	3.45
13	50	9.06	8.86	.20	2.26
May 10	50	8.95	8.51	.44	5.17
June 7	50	9.19	8.79	.40	4.55
9	50	9.41	8.58	.83	9.67

TABLE 26.—*Comparison of yield of raw and pasteurized-milk cheese after curing for various lengths of time at Madison, Wis.*—Continued.

Date made.	Time cured after paraffining.	Weight of cured cheese per 100 pounds of milk.		Gain by pasteurization.	
		Pasteurized.	Raw.		
1911.	*Days.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
July 3	51	9.05	8.38	0.67	8.00
6	51	9.35	9.21	.14	1.52
June 1	55	9.59	9.49	.10	1.05
2	55	9.33	8.95	.38	4.24
May 29	55	9.52	9.05	.47	5.19
Apr. 25	56	9.62	9.07	.55	6.06
May 2	58	9.32	9.06	.26	2.87
3	58	8.82	8.66	.16	1.84
Apr. 7	56	9.36	8.89	.47	5.28
May 25	62	9.19	8.86	.33	3.72
22	62	9.40	8.74	.66	7.55
26	61	9.16	8.80	.36	4.09
27	61	9.38	8.95	.47	5.25
28	61	9.67	9.35	.32	3.42
19	66	9.66	8.90	.76	8.54
21	66	9.16	8.72	.44	5.05
Apr. 28	65	8.97	8.82	.15	1.70
27	65	8.78	8.10	.68	8.40
24	65	9.01	8.68	.33	3.80
Mar. 10	68	9.10	8.85	25	2.82
21	68	9.15	8.67	.48	5.53
20	68	9.15	8.74	.41	4.69
Apr. 17	72	9.03	8.47	.56	6.61
18	72	8.81	8.34	.47	5.63
Mar. 17	74	9.43	9.28	.15	1.62
16	74	9.72	9.55	.17	1.78
15	74	9.34	9.06	.28	3.09
14	74	9.62	8.99	.63	7.01
14	74	9.37	8.53	.84	9.84
Apr. 13	80	8.76	8.58	.18	2.09
11	80	8.98	8.74	.24	2.74
7	86	9.09	8.68	.41	4.72
5	86	9.33	8.88	.45	5.07
Mar. 9	84	9.24	8.94	.30	3.35
8	84	9.40	9.09	.31	3.41
7	84	9.39	9.13	.26	2.85
3	84	9.24	9.02	.22	2.44
2	87	8.93	8.64	.29	3.35
1	87	8.97	8.85	.12	1.35
Feb. 28	87	9.25	8.71	.54	6.20
27	87	9.28	8.78	.50	5.69
24	87	8.98	8.72	.26	2.98
Mar. 20	98	8.94	8.62	.32	3.71
21	98	8.95	8.44	.51	6.04
22	98	8.91	8.69	.22	2.53
17	104	9.20	9.08	.12	1.32
16	104	9.51	9.35	.16	1.71
15	104	9.12	8.92	.20	2.24
14	104	9.41	8.83	.58	6.57
13	104	9.14	8.46	.68	8.03
9	114	9.02	8.72	.30	3.44
8	114	9.14	8.88	.26	2.93
7	114	9.14	8.93	.21	2.35
3	114	9.06	8.85	.21	2.37
2	117	8.80	8.51	.29	3.41
1	117	8.86	8.75	.11	1.25
Feb. 28	117	9.12	8.63	.49	5.67
27	117	9.15	8.69	.46	5.29
24	117	8.79	8.62	.17	1.97
Average	....	9.289	8.907	.38	4.22

Cheese stored at New Orleans (lots 1B to 4B).—Fifty-four days' make represented by 54 raw and 54 pasteurized-milk cheeses were shipped to New Orleans in four lots at different times during the season. These cheeses showed an increased yield for the new-process cheese, as compared with the old, in every case. The average figures for each lot are given in Table 27.

TABLE 27.—*Average yield per 100 pounds of milk of raw and pasteurized-milk cheese cured at New Orleans.*

Lot No.	Method.	Number of days' make.	Yield of cheese per 100 pounds of milk.						
			Green.	Paraffined.	Shipped to New Orleans.	Received at New Orleans.	Stored one month.	Stored two months.	Received at Madison.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1B	Pasteurized	25	10.19	9.69	9.55	9.52	8.85	8.38	8.31
	Raw	25	9.67	9.26	9.16	9.14	8.36	7.85	7.78
	Gain, pounds		.52	.43	.39	.38	.49	.53	.53
	Gain, per cent		5.37	4.64	4.25	4.16	5.86	6.75	6.81
2B	Pasteurized	9	9.83	9.40	9.37	9.26	8.48		8.40
	Raw	9	9.45	9.08	9.05	8.97	8.12		8.01
	Gain, pounds		.38	.32	.32	.29	.36		.39
	Gain, per cent		4 02	3.52	3.54	3.23	4.43		4.87
3B	Pasteurized	10	10.47	9.99	9.92	9.77	9.29		9.17
	Raw	10	9.93	9.54	9.47	9.34	8.69		8.55
	Gain, pounds		.54	.45	.45	.43	.60		.62
	Gain, per cent		5.44	4.72	4.75	4.60	6.90		7.25
4B	Pasteurized	10	10.38	9.92	9.83	9.78	8.94		8.71
	Raw	10	9.69	9.31	9.24	9.19	8.28		8.14
	Gain, pounds		.69	.61	.59	.59	.66		.57
	Gain, per cent		7.12	6.55	6.38	6.42	7.97		7.00
1-4B	Pasteurized	54	10.22	9.74	9.64	9.57	8.89		8.56
	Raw	54	9.68	9.29	9.21	9.16	8.37		8.03
	Gain, pounds		.54	.45	.43	.41	.52		.53
	Gain, per cent		5.58	4.84	4.67	4.47	6.21		6.60

Among the four lots in Table 27, and in the summary at the bottom of the table, it will be seen that the percentage of gain in yield of pasteurized cheese over raw fell off slowly as the green cheeses were paraffined and shipped, on the average from 5.58 to 4.47 per cent. After these cheeses had been in storage at New Orleans for one month, the raw-milk cheeses were found to have shrunk more than the pasteurized in the majority of cases, raising the percentage of gain in average yield of pasteurized cheese to 6.21 per cent. This was also observed in lot 1B after the second month of storage, and is confirmed both by the weights taken in New Orleans by Mr. Bleecker and by the weights taken at Madison. It was expected that the pasteurized-milk cheese, containing slightly more moisture than the raw-milk cheese, would lose more in weight than the latter when stored at high temperatures. It was surprising to find that the reverse is true in most cases.

The mean daily temperature at New Orleans, as reported by the United States Weather Bureau, varied from 71, the average for April, to 83, the average for June. It is likely that the temperature of the cheese in the warehouse was somewhat higher than the average figures given above, because the warehouse, although well ventilated,

was necessarily open more or less during the hot days and closed during the cool nights.

Cheese cured at New Orleans and at Columbus, Ga. (lots 3C and 4C).—Forty cheeses, including 20 pasteurized and 20 raw, were shipped in two shipments for storage in the South through a firm[1] of cheese dealers in Chicago, who weighed the cheese, both before and after storage for one month.

In the first shipment 1 cheese, No. 243-3, was lost in transit, and in the second shipment, 2 cheeses, Nos. 254-1 and 254C1, were damaged so that their weights are not included in the following summary. In the first shipment, according to the Chicago weights, 9 pasteurized-milk cheeses weighed 172½ pounds before storage and 162¼ pounds afterwards. The loss, 10¼ pounds, is 5.94 per cent of the original weight. In the same shipment 10 raw-milk cheeses weighed 189¼ pounds before shipment and 175 pounds afterwards. The loss here, 14¼ pounds, is 7.53 per cent of the original weight.

In the second shipment nine pasteurized-milk cheeses weighed 176½ pounds before and 159¾ pounds after storage. The loss, 16¾ pounds, is 9.49 per cent of the original weight of the cheese. In the same shipment nine raw-milk cheeses weighed 161 pounds before and 144¾ pounds after storage. The loss in this case, 16¼ pounds, is 10.09 per cent of the original weight. In both shipments the raw-milk cheese lost a greater per cent of their weight than the pasteurized-milk cheese. On comparing the individual cheeses in pairs, it was found that in most cases the pasteurized-milk cheese lost less than the raw-milk cheese, although in a few cases the reverse was true.

The weights taken at Madison on the same lots of cheese gave the figures shown in Table 28, agreeing substantially with the results obtained at Chicago:

TABLE 28.—*Average yield per hundred pounds of milk of raw and pasteurized milk cheese cured in the South.*

Lot No.	Method.	Number of days' make.	Weight of cheese per 100 pounds of milk.			
			Green.	Paraffined.	Shipped from Madison.	Received at Madison.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
3C	Pasteurized	9	10.47	9.99	9.92	9.24
	Raw	10	9.93	9.54	9.46	8.68
	Gain, pounds		.54	.45	.46	.56
	Gain, per cent		5.44	4.72	4.86	6.44
4C	Pasteurized	9	10.38	9.92	9.84	8.83
	Raw	9	9.69	9.31	9.24	8.24
	Gain, pounds		.69	.61	.60	.59
	Gain, per cent		7.12	6.55	6.49	7.16

[1] We are indebted to Messrs. Crosby & Meyers for their kind cooperation in this work.

Cheese cured in a warm room (lots 3D and 4D).—To further test the effect of storage at high temperature 40 cheeses, lots 3D and 4D, were put for 47 days into a warm curing room at Madison where the temperature was held at 75° to 85°.

TABLE 29.—*Average yield per hundred pounds of milk of raw and pasteurized milk cheese cured in warm room.*

Lot No.	Method.	Number of days' make.	Weight of cheese per 100 pounds of milk.			
			Green.	Paraffined.	Put in warm room.	Taken out of warm room.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
3D	Pasteurized	10	10.47	9.99	9.91	9.37
	Raw	9	9.93	9.54	9.46	8.88
	Gain, pounds		.54	.45	.45	.49
	Gain, per cent		5.44	4.72	4.75	5.52
4D	Pasteurized	9	10.38	9.92	9.85	9.33
	Raw	10	9.69	9.31	9.23	8.73
	Gain, pounds		.69	.61	.62	.60
	Gain, per cent		7.12	6.55	6.72	6.87

From these results with eight lots of cheese—1B, 2B, 3B, 4B, 3C, 4C, 3D, and 4D—it can be stated with certainty that pasteurized-milk cheese does not lose more in weight than raw-milk cheese when stored in warm rooms or in the South, after paraffining. On the contrary, the pasteurized-milk cheese lost on the average a smaller percentage of weight in warm storage than the raw-milk cheese. At first this fact seemed inexplicable, but the reason became clearly apparent from inspection of the cheese kept in the warm curing room at Madison.

Within a few days after going into the warm room the raw-milk cheese became very greasy on the surface, and the grease running on to the shelves and the floor marked the spot where each cheese stood. The pasteurized-milk cheese, standing alongside of them on the same shelves, did not exude grease, or only very slightly in a few cases, and the difference between the greasy raw-milk cheese and the dry surface of the pasteurized-milk cheese was so marked that there was no difficulty in picking out each kind by the sense of touch alone.

To demonstrate further the difference in this respect, each cheese of the last lot when put into the warm room was placed on a piece of wire gauze in a shallow tin pan, so that the grease running from each cheese could be collected. A very little of the paraffin was scraped from the surface of each cheese by contact with the wire gauze in the bottom of the pan. The total weight of material, practically all paraffin, collected from the 10 pasteurized-milk cheeses weighed 0.13 of a pound, while the material, mostly fat, with a little paraffin and mold, collected from the raw-milk cheeses, weighed 1.92 pounds, which is 1.2 per cent of the weight of the raw cheese when placed in the storeroom.

At present we are unable to explain with certainty why the pasteurized-milk cheese should lose fat less readily when stored at 70° to 80° than the raw-milk cheese. Further study will be made of this phenomenon. The purpose of beginning these studies of losses of weight in warm rooms was to determine whether the increased yield obtained by pasteurization would be offset by increased losses in weight when pasteurized-milk cheese are shipped to the South, and it is now fully demonstrated that the pasteurized-milk cheese stored in the South maintain their advantage as to increased yield.

Cheese placed in cold storage at Waterloo, Wis. (lot 5E).—The losses of weight observed in 35 pasteurized-milk cheeses put into cold storage[1] at 34° at different ages are shown in Table 30. The cheese represent seven days' make during July and August, 1911.

TABLE 30.—*Shrinkage of pasteurized-milk cheese in cold storage.*

Date made.	Cheese No.	Weight, green.	When paraffined.		When put into cold storage.		When taken out of cold storage.		Total shrinkage.	
			Age.	Weight.	Age.	Weight.	Age.	Weight.		
1911.		*Pounds.*	*Days.*	*Pounds.*	*Days.*	*Pounds.*	*Days.*	*Pounds.*	*Pounds.*	*Per cent.*
July 19	264-1	20.60	9	19.60	([2])	([2])	100	18.15	2.45	11.89
19	264-2	21.11	1	20.70	1	20.70	100	20.38	.73	3.45
19	264-3	20.10	7	19.21	7	19.21	100	19.15	.95	4.72
19	264-4	21.07	9	20.05	14	20.04	100	19.85	1.22	5.79
19	264-5	19.89	9	18.90	28	18.70	100	18.28	1.61	8.09
19	264-6	20.45	9	19.44	41	18.95	100	18.65	1.80	8.80
21	265-1	22.49	8	21.60	([2])	([2])	99	20.10	2.39	10.62
21	265-2	17.98	1	17.58	1	17.58	99	17.45	.53	2.94
21	265-3	20.21	7	19.35	7	19.35	99	19.25	.96	4.75
21	265-4	18.86	8	17.98	14	17.92	99	17.75	1.11	5.89
21	265-5	19.58	8	18.68	28	18.42	99	18.05	1.53	7.81
21	265-6	19.25	8	18.40	28	18.13	99	17.68	1.57	8.16
21	265-7	19.75	8	18.86	40	18.36	99	18.10	1.65	8.35
25	267-1	20.82	11	19.86	([2])	([2])	95	18.50	2.32	11.14
25	267-2	20.29	1	19.95	1	19.95	95	19.80	.49	2.41
25	267-3	19.97	7	19.11	7	19.11	95	18.90	1.07	5.35
25	267-4	21.55	11	20.58	14	20.58	95	20.38	1.17	5.43
25	267-5	20.23	11	19.25	29	18.98	95	18.58	1.65	8.15
25	267-6	22.20	11	21.31	43	20.62	95	20.25	1.95	8.78
27	269-1	18.70	9	17.80	([2])	([2])	93	16.45	2.25	12.03
27	269-2	19.88	1	19.45	1	19.45	93	19.20	.68	3.42
27	269-3	19.85	7	19.01	7	19.01	93	18.95	.90	4.53
27	269-4	20.87	9	19.92	14	19.92	93	19.55	1.32	6.32
27	269-5	18.80	9	17.91	27	17.60	93	17.22	1.58	8.40
27	269-6	20.22	9	19.22	41	18.61	93	18.25	1.97	9.74
Aug. 1	272-1	21.91	11	20.65	([2])	([2])	89	19.00	2.91	13.28
1	272-2	19.78	1	19.30	1	19.30	89	19.05	.73	3.69
1	272-3	19.40	7	18.55	7	18.55	89	18.22	1.18	6.08
1	272-4	21.82	11	20.55	14	20.55	89	20.25	1.57	7.19
1	272-5	21.80	11	20.57	29	20.26	89	19.90	1.90	8.71
1	272-6	21.75	11	20.50	46	19.75	89	19.50	2.25	10.34
1	276-1	19.90	11	18.63	([2])	([2])	81	17.20	2.70	13.56
8	276-2	20.42	1	19.98	1	19.98	81	19.60	.82	4.01
8	276-3	20.44	7	19.50	7	19.50	81	19.30	1.14	5.57
8	276-4	19.90	11	18.66	15	18.63	81	18.40	1.50	7.53
8	276-5	19.70	11	18.45	28	18.21	81	17.75	1.95	9.89
22	283-1	20.10	......	....	([2])	([2])	67	18.10	2.00	9.95
22	283-2	19.90	1	19.50	1	19.50	67	19.38	.52	2.61
22	283-3	19.68	8	18.81	8	18.81	67	18.75	.93	4.72
22	283-4	18.80	11	17.90	15	17.70	67	17.40	1.40	7.44
22	283-5	19.84	11	18.84	29	18.62	67	18.45	1.39	7.00
22	283-6	18.65	11	17.62	42	([2])	67	16.80	1.85	9.92

SUMMARY.

No. of cheese	7	7	7	7	6	7
Age when stored	1 day.	1 week.	2 weeks.	4 weeks.	6 weeks.	In cellar.
Average total shrinkage, per cent	3.22	5.10	6.51	8.29	9.29	11.78

[1] In warehouse at Waterloo, Wis., by courtesy of the Roach & Seeber Co.

[2] Cured in cellar.

Although the seven cheeses put into storage at the age of 1 day showed an average of only 3.22 per cent shrinkage after three months, yet they were not well broken down and required further curing at 60° to 70° to get rid of their curdy, lumpy texture. The cheese paraffined and stored when 1 week old showed an average total shrinkage of 5.10 per cent, and these were found to be thoroughly broken down when taken out of cold storage. This series appears to indicate that the quality of pasteurized-milk cheese is not damaged by placing in cold storage at the age of 1 week, while the shrinkage (5.10 per cent) is about half that of the duplicate cheese, cured in the cellar at Madison (11.78 per cent), as shown at the bottom of the table.

THE CAUSES OF THE INCREASED YIELD FROM PASTEURIZED MILK.

THE LOSSES OF FAT FROM VAT AND PRESS.

The increased yield of green cheese from pasteurized milk, amounting to over 5 per cent (Table 20), is due partly to the fact that about half of the fat lost in the whey and drippings by the old process is retained in the cheese by the new process of making. Also it is found that a little more moisture can safely be incorporated in the new-process cheese without danger of spoiling it, but on the contrary giving it a moist, fat appearance which consumers generally like. The loss of fat in the whey is caused partly by the passage of the curd knives through the curd in cutting, at which time a considerable proportion of fat is brushed away from the surface of the curd cubes. During the stirring and heating some further fat globules are lost from the curd cubes, and still further losses occur after milling and during pressing. In the new process of making cheese from pasteurized milk the curd is so firm and elastic (not brittle) at the time of cutting that the loss of fat in the whey averages only about one-half that observed in cheese making by the ordinary process.

The average fat content of whey from good clean milk is stated to be 0.30 per cent and from average cheese factory milk 0.36 per cent.[1] On a great many days during the past two and one-half years the milk supply in the receiving vat has been divided and one half made up by the regular methods and the other half by the new method. The quality and composition of the milk was thus the same in both vats. On the 24 days listed in Table 31 the average fat content of the whey from the regular vats was 0.25 per cent and from the pasteurized-milk vats was 0.159 per cent.

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[1] Van Slyke and Publow, loc. cit., pp. 189, 190.

TABLE 31.—*Comparison of the percentage of fat in whey by new method and by regular method of cheese making.*

Date.	Fat in milk.	New method.		Regular method.	
		Weight of milk used.	Fat in whey when drawn.	Weight of milk used.	Fat in whey when drawn.
1911.	*Per ct.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
Aug. 29	4.1	294½	0.14	290	0.17
30	3.6	344	.14	344	.26
Sept. 1	....	322	.15	320	.20
5	4.0	291½	.17	292	.28
6	3.6	276	.19	276	.32
7	4.1	286½	.18	286½	.32
8	....	292	.16	795	.26
1909.					
July 21	4.0	200	.15	200	.21
22	3.9	200	.12	200	.20
23	4.0	200	.15	200	.19
24	4.0	200	.12	200	.22
Aug. 12	3.7	200	.16	200	.26
1908.					
July 18	4.1	200	.12	200	.22
Oct. 1	4.7	200	.20	200	.30
2	4.5	200	.18	200	.29
7	4.4	200	.14	200	.19
8	4.0	200	.15	200	.25
Sept. 1	4.3	200	.17	200	.32
2	4.2	200	.18	200	.30
14	4.2	200	.18	200	.24
16	4.0	200	.13	200	.27
17	4.4	200	.19	200	.29
18	4.4	200	.18	200	.25
19	4.2	200	.17	200	.23
Average	....	....	.159	....	.25

In these cases the small amount of milk handled in each vat permitted hand stirring, and neither the rake nor the agitator was used. By this means the whey fat of the regular-process vats was kept at a lower figure, perhaps, than could have been done with large vats, as handled in a commercial factory using the regular process.

On 22 days, using 1,200 to 2,000 pounds of pasteurized milk in each vat, the percentage of fat in the whey at the time of drawing the whey averaged 0.17 per cent, as shown in the following table. In these cases the vats were stirred with an agitator.

TABLE 32.—*Fat content of whey from pasteurized-milk cheese.*

Date.	Fat in whey two hours after cutting.	Weight of milk handled.	Weight of cheese.
1910.	*Per cent.*	*Pounds.*	*Pounds.*
May 25	0.14	1,234	139
26	.16	1,322	153
27	.18	1,337	144
June 1	.17	1,578	166
6	.12	2,061	226
7	.15	1,427	159
8	.14	1,431	158
9	.18	1,360	147
10	.17	1,448	162

TABLE 32.—*Fat content of whey from pasteurized-milk cheese*—Continued.

Date.	Fat in whey two hours after cutting.	Weight of milk handled.	Weight of cheese.
1910.	*Per cent.*	*Pounds.*	*Pounds.*
June 14	0.20	1,398	148
16	.20	1,165	126
17	.20	1,320	152
20	.20	1,588	170
21	.23	1,292	144
22	.14	1,347	144
23	.16	1,329	139
24	.18	1,337	139
28	.24	1,277	130
29	.14	1,210	130
30	.17	1,243	131
July 5	.18	1,242	125
6	.14	1,229	134
Average..	.17	....	....

Most of the loss of fat from curd occurs at the moment of cutting, as shown by the figures in Table 33. On 23 days samples of whey were taken daily from the vat as soon after cutting as it was possible to obtain any clear whey—that is, in four to six minutes. The fat content of this whey, sampled five minutes after cutting, tested 0.47 per cent on the average of 23 days, while the average test of samples taken from the same vats two hours after cutting was 0.16 per cent. The average weight of milk handled daily in the vat was 1,110 pounds, and the average fat test of the milk was 4 per cent.

TABLE 33.—*Fat content of whey at time of cutting curd and 2 hours later.*

Date.	Time after cutting curd.		Weight of milk handled.	Weight of cheese.
	4 to 6 minutes.	2 hours.		
1910.	*% fat.*	*% fat.*	*Pounds.*	*Pounds.*
Apr. 8	0.45	0.16	1,011	102
12	.46	.19	1,011	104
13	.40	.15	967	98
14	.40	.14	1,045	108
15	.50	.12	1,001	100
18	.35	.13	993	103
19	.55	.22	906	97
22	.40	.16	755	77
25	.42	.19	1,065	117
26	.52	.17	940	103
27	.52	.16	1,004	109
28	.57	.15	972	102
29	.45	.14	796	102
May 3	.65	.16	1,041	122
4	.67	.16	1,055	118
5	.52	.17	1,119	129
6	.50	.20	917	97
10	.52	.16	1,288	141
11	.50	.15	1,285	138
18	.35	.15	1,239	137
19	.40	.14	1,186	130
23	.25	.12	2,477	268
24	.45	.19	1,454	154
Average..	.47	.16	1,110	119.8

The reason for the decrease in percentage of fat in whey at two hours after cutting is that there was little fat lost from the curd during the time the whey was being expelled, so that the fat lost from the curd cubes at the moment of cutting was diluted about 0.47 divided by 0.16 = 3 times by the water expelled from the curd during the two-hour period.

Losses of fat after drawing the whey.—On several days the whey drippings from the pasteurized-milk curd, from the time the curd was all on the rack up to the time when it was taken from the press, were collected, weighed, and tested for fat. From this could be calculated the weight of fat lost in the drippings, as shown in Tables 34, 35, and 36:

TABLE 34.—*Loss of fat in drippings in 2 hours and 50 minutes—From dipping to hooping—Pasteurized-milk curd.*

Date.	Total weight of drippings collected.	Fat in drippings.		Weight of cheese made.
1910.	*Pounds.*	*Per cent.*	*Pound.*	*Pounds.*
Apr. 12	29	0.27	0.078	104
13	28	.27	.075	98
14	31	.30	.093	108
15	33	.25	.082	100
18	21	.20	.042	103
19	26	.10	.026	97
20	20	.15	.030	91½
21	25	.18	.045	95½
22	21	.12	.025	77
25	24	.20	.048	117
Total.....	258	....	.544	991

TABLE 35.—*Losses of fat in drippings before pressing pasteurized-milk curds.*

Date.	Drippings in 1½ hours—dipping to milling.			Drippings in 1⅓ hours—milling to hooping.			Weight of cheese.
	Weight.	Fat content.		Weight.	Fat content.		
1910.	*Pounds.*	*Per cent.*	*Pound.*	*Pounds.*	*Per cent.*	*Pound.*	*Pounds.*
Apr. 27	35	0.02	0.007	5.0	1.8	0.090	109
28	24	.05	.012	5.0	1.8	.090	102
29	24	.02	.050	3.0	1.8	.054	84
May 3	25	.08	.020	2.5	1.8	.045	122½
4	25	.05	.012	1.5	.6	.009	118
5	29	.07	.020	3.0	1.7	.051	129
10	26	.07	.018	4.0	1.2	.048	141
11	24	.07	.017	3.0	1.6	.048	137½
13	25	.16	.040	3.0	2.0	.060	103
18	24	.06	.014	4.5	2.0	.090	137
19	25	.05	.012	5.0	1.4	.070	125
23	38	.04	.015	9.0	1.5	.135	268
24	26	.14	.036	5.0	2.0	.100	162
Total.......	350	....	.273	53.5	....	.890	1,738
Calculated for 10 lbs. of cheese...	2.01	....	.00157	.3078	....	.00512	....

TABLE 36.—*Loss of fat in drippings from pasteurized-milk cheese in press.*

Date.	Total weight of cheese pressed.	Total weight of drippings.	Fat in drippings.	
	Pounds.	*Pounds.*	*Per cent.*	*Pounds.*
1910.				
May 16-20	808	24	3.85	0.92
23-27	873	32	3.2	1.02
Total	1,681	56	....	1.94
Calculated for 10 lbs. of cheese	....	.33	....	.0115

Summary of losses of fat by the new method of cheese making.—The total loss of fat from cheese in the new process is about 1.6 per cent of the weight of the cheese, as shown in the following summary of the preceding tables:

TABLE 37.—*Total losses of fat in making 10 pounds of cheese from pasteurized milk.*

Period.	Total weight.	Fat content.		Loss of fat from cheese.
	Pounds.	*Per cent.*	*Pound.*	*Per cent.*
Whey when drawn	87.4	0.16	0.1400	1.400
Drippings from curd before milling	2.01	.08	.0016	.016
Drippings from curd in vat after milling	.31	1.66	.0051	.051
Drippings from press	.33	3.46	.115	.115
Total	90.05	....	.1583	1.583

The average total loss of fat from 100 pounds of milk handled by the new process of cheese making is seen to be on the average 0.158 pounds of fat, or a little less than 4 per cent of the total fat content of milk containing 4 per cent fat. The loss of fat from 100 pounds of milk in ordinary cheese making under average factory conditions has been found to amount to 0.33 of a pound of fat, or 0.36 per cent of fat in the whey, or 9 per cent of the total fat content of the milk.[1]

It will be seen from these figures that the loss of fat is reduced to less than one-half by the new process of cheese making. It might be expected from this statement that each day's make of pasteurized-milk cheese tested by the Babcock test would show a higher percentage of fat than the same day's raw-milk cheese. In Table 38, however, it is seen that in 15 cases out of 21 the pasteurized-milk cheese tested lower in fat (0.65 per cent lower on the average) than the raw-milk cheese.

THE INCREASED MOISTURE CONTENT OF PASTEURIZED-MILK CHEESE.

This is due to the fact that there is an increased content of moisture as well as of fat in the new-process cheese, and in most cases the increase of moisture is greater than the increase of fat. On this

[1] Van Slyke and Publow, loc. cit., p. 189.

account the moisture content of pasteurized cheese listed in the table below is greater than that of the raw-milk cheese in 29 cases out of 33, and the average percentage was 1.68 greater.

The cheeses listed in the table were the same as those in Table 26, and the testing for fat and moisture was done immediately after the last weights had been taken for the determination of yield and shrinkage. The samples of cheese weighed into the Babcock test bottles were rapidly dissolved in a mixture of hot water and sulphuric acid, as suggested by one of us in a previous paper.[1]

TABLE 38.—*Comparison of the fat and moisture content of raw and pasteurized milk cheese cured at Madison.*

Date.	Moisture content of cheese.				Fat content of cheese.			
	Pasteurized.	Raw.	Difference.		Pasteurized.	Raw.	Difference.	
1911.	*Per ct.*	*Per ct.*	+*Per ct.*	−*Per ct.*	*Per ct.*	*Per ct.*	−*Per ct.*	+*Per ct.*
Feb. 24	30.50	30.15	0.35		38.86	39.10	0.24	
27	33.55	30.15	3.40					
28	32.52	30.05	2.47					
Mar. 1	32.55	31.25	1.30					
2	31.60	30.75	.85					
3	31.05	31.47		0.42				
7	31.90	29.75	2.15		37.44	38.16	.72	
8	32.37	30.17	2.20		37.99	38.16	.17	
9	32.77	31.32	1.45		38.61	38.04		0 57
10	32.45	31.45	1.00					
13	33.15	30.00	3.15					
14	33.51	31.95	1.56					
15	31.62	30.90	.72		38.28	38.36	.08	
16	33.40	30.87	2.53		38.61	38.39		.22
17	34.15	33.22	.93		38.01	37.97		.04
20	32.72	31.58	1.14					
21	32.90	30.10	2.80					
22	34.00	32.20	1.80					
Apr. 5	34.10	32.25	1.85		36.93	37.09	.16	
7	34.52	31.92	2.60		36.56	36.85	.29	
11	32.90	31.97	.93					
13	31.78	30.17	1.61		36.84	37.02	.18	
17	33.47	31 55	1.92		36.81	37.94	1.13	
18	33.55	30.15	3.40		38.22	39.95	1.73	
24	32.28	32.68		.40	39.18	38.86		.32
27	31.80	32.70		.90	38.64	38.66	.02	
28	34.17	33.22	.95		37.93	39.08	1.15	
May 2	32.63	31.25	1.38		39.55	40.68	1.13	
3	31 02	30.87	.15		40.68	41.43	.75	
8	32.87	31.05	1.82		37.97	39.06	1.09	
10	31.65	30.45	1.20		39.28	39.27		.01
15	33.47	32.25	1.22		37.97	38.66	.69	
17	31.87	32.58		.71	38.10	37.67		.43
Average..	32.69	31.28	1.68	.61	38.21	38.59	.65	.26

The combined effect upon the percentage composition of cheese caused by increasing both the fat and moisture content is shown in the following example:

Ten pounds of raw-milk cheese of the same average percentage composition as in Table 38, as shown at I, below, would contain the weights of fat, moisture, and casein, etc., shown at II. If by pasteurization the fat content of the cheese is increased about 4 per cent of itself, and the moisture content is increased about 12½ per cent of itself, there will be obtained 10.54 pounds of pasteurized-milk cheese

[1] Sammis, J. L. The determination of fat in cheese by the Babcock test. Journal of Industrial and Engineering Chemistry, vol. 1, no. 8, p. 604. Easton, Pa., Aug., 1909.

as shown at III instead of 10 pounds of raw-milk cheese, a theoretical gain of 5.4 per cent in the yield of cheese. (The actual gain shown in Table 20 was 5.37 per cent.) The percentage composition of this pasteurized cheese will be as shown at IV, which agrees closely with the average composition of the pasteurized-milk cheese shown at the bottom of Table 38.

	I.	II.		III.	IV.
Fat......	38.59 per cent.	3.859 pounds+0.154 pounds=		4.013 pounds.	38.07 per cent.
Moisture..	31.28 per cent.	3.128 pounds+0.391 pounds=		3.519 pounds.	33.37 per cent.
Casein, etc.	30.13 per cent.	3.013 pounds+.... pounds=		3.013 pounds.	28.57 per cent.
	100.00 per cent.	10.000 pounds.		10.545 pounds.	100.00 per cent.

The increased moisture content of pasteurized-milk cheese made by this process is due to the effect of pasteurization on the properties of curd, as stated on page 25.

THE QUALITY OF PASTEURIZED-MILK CHEESE.

SCORES AND CRITICISMS OF PASTEURIZED AND RAW MILK CHEESE.

The milk supply used at Madison is no better than the average cheese-factory milk. Sunday's milk is delivered on Monday throughout the year and is therefore inferior to that of the other days. Cheese from every day's make during the season was scored by two judges, Mr. U. S. Baer, assistant dairy and food commissioner of the State of Wisconsin, and Mr. A. T. Bruhn, junior dairyman, United States Department of Agriculture, who during the past year have scored the cheese sent to the monthly scoring exhibition, conducted by the Wisconsin Experiment Station. The judges worked independently and pinned their scoresheets to each cheese without knowing even the numbers of the cheese, which were turned toward the wall. Their scores show close agreement with each other in most cases and leave no doubt as to the relative quality of the cheese scored. After finishing about 20 of the cheeses, they turned them around and added the cheese numbers to the sheets. In general, a score of 92 or above indicates that the cheese is of good quality and salable at full market price. A cheese scored below 92 is likely to be cut in price in a dull market. Tables 39 to 46 show the scores of both judges as well as the average scores, which latter are used in the discussion. Raw-milk cheese is in all cases indicated by the letter C attached to the serial number.

CHEESE CURED AT MADISON AT NORMAL TEMPERATURE.

Lots 1A, 2A, 3A, and 4A.—These lots include 53 pairs of cheese cured in the cellar at Madison. The temperature of the curing room showed daily about 3° to 5° difference between maximum and minimum and ranged from 60° to 73° from February to July, 1911. By opening the windows at night only, it was kept at 60° to 70° from July to October.

The scores of the 53 pairs of cheese are as shown in Table 39. The average score of all the pasteurized-milk cheese is 92.75 and of the raw-milk cheese 89.09.

TABLE 39.—*Scores of 53 pairs of raw and pasteurized cheese (lots 1A, 2A, 3A, and 4A) cured at Madison.*

LOTS 1A AND 2A, SCORED JULY 17, 1911.

Temperature of curing room 8 a. m.	Date made.	Cheese No.[1]	Scored by U. S. Baer.			Scored by A. T. Bruhn.			Average.		
			Flavor.	Texture.	Total.	Flavor.	Texture.	Total.	Flavor.	Texture.	Total.
°F.	1911.										
....	Feb. 24	172	41.0	26.0	92.0	40.0	26.5	91.5	40.50	26.25	91.75
....	24	172C	37.0	27.0	89.0	38.0	27.0	90.0	37.50	27.00	89.50
....	27	173	43.0	28.5	96.5	42.5	28.0	95.5	42.75	28.25	96.00
....	27	173C	38.0	27.0	90.0	40.0	27.0	92.0	39.00	27.00	91.00
....	28	174	41.0	27.0	93.0	41.0	27.5	93.5	41.00	27.25	93.25
....	28	174C	39.0	26.0	90.0	39.0	26.5	90.5	39.00	26.25	90.25
....	Mar. 1	175	41.0	27.0	93.0	40.0	26.0	91.0	40.50	26.50	92.00
....	1	175C	40.0	26.0	91.0	40.0	26.5	91.5	40.00	26.25	91.25
....	2	176	40.0	28.0	93.0	41.0	27.0	93.0	40.50	27.50	93.00
....	2	176C	37.0	27.0	89.0	39.0	27.0	91.0	38.00	27.00	90.00
....	3	177	40.0	27.0	92.0	40.0	26.5	91.5	40.00	26.75	91.75
....	3	177C	38.0	26.0	89.0	38.0	26.0	89.0	38.00	26.00	89.00
....	7	178	40.0	26.0	91.0	40.0	27.0	92.0	40.00	26.50	91.50
....	7	178C	38.0	27.0	90.0	39.0	27.0	91.0	38.50	27.00	90.50
....	8	179	40.0	27.0	92.0	41.0	27.5	93.5	40.50	27.25	92.75
....	8	179C	35.0	26.0	86.0	38.0	26.0	89.0	36.50	26.00	87.50
....	9	180	41.0	26.0	92.0	41.0	27.0	93.0	41.00	26.50	92.50
....	9	180C	39.0	26.0	90.0	40.5	26.5	92.0	39.75	26.25	91.00
....	10	181	41.0	26.0	92.0	42.0	27.0	94.0	41.50	26.50	93.00
....	10	181C	38.0	27.0	90.0	39.0	26.5	90.5	38.50	26.75	90.25
....	13	182	40.0	27.0	92.0	41.0	27.0	93.0	40.50	27.00	92.50
....	13	182C	41.0	26.0	92.0	40.0	27.0	92.0	40.50	26.50	92.00
....	14	183	40.0	26.0	91.0	40.0	26.5	91.5	40.00	26.25	91.25
....	14	183C	40.0	27.0	92.0	40.0	26.5	91.5	40.00	26.75	91.75
....	15	184	40.0	26.0	91.0	41.0	27.0	93.0	40.50	26.50	92.00
....	15	184C	40.0	27.0	92.0	41.5	27.0	93.5	40.75	27.00	92.75
60	16	185	40.0	26.0	91.0	41.5	27.0	93.5	40.75	26.50	92.25
....	16	185C	35.0	26.0	86.0	41.0	27.0	93.0	38.00	26.50	89.50
62	17	186	42.0	28.0	95.0	41.0	26.5	92.5	41.50	27.25	93.75
....	17	186C	41.0	28.0	94.0	41.0	27.0	93.0	41.00	27.50	93.50
63	20	187	43.0	27.0	95.0	41.0	26.0	92.0	42.00	26.50	93.50
....	20	187C	35.0	25.0	85.0	39.0	26.5	90.5	37.00	25.75	87.75
66	21	188	43.0	28.0	96.0	41.0	27.0	93.0	42.00	27.50	94.50
....	21	188C	38.0	26.0	89.0	40.0	27.0	92.0	39.00	26.50	90.50
66	22	189	43.0	27.0	95.0	42.0	28.0	95.0	42.50	27.50	95.00
....	22	189C	39.0	27.0	91.0	40.0	27.0	92.0	39.50	27.00	91.50
62	Apr. 5	198	43.0	27.0	95.0	42.0	28.0	95.0	42.50	27.50	95.00
....	5	198C	41.0	27.0	93.0	41.5	28.0	94.5	41.25	27.50	93.75
....	7	200	42.0	27.0	94.0	42.0	27.0	94.0	42.00	27.00	94.00
64	7	200C	35.0	25.0	85.0	40.0	26.0	91.0	37.50	25.50	88.00
....	11	202	42.0	26.0	93.0	42.5	27.0	94.5	42.25	26.50	93.75
....	11	202C	39.0	26.0	90.0	40.0	27.0	92.0	39.50	26.50	91.00
....	13	204	41.0	27.0	93.0	42.0	28.0	95.0	41.50	27.50	94.00
....	13	204C	39.0	26.0	90.0	40.0	27.0	92.0	39.50	26.50	91.00
....	17	206	41.0	27.0	93.0	41.0	27.0	93.0	41.00	27.00	93.00
....	17	206C	40.0	25.0	90.0	38.0	25.0	87.0	39.00	25.00	88.50
....	18	207	43.0	26.0	94.0	41.5	27.0	93.5	42.25	26.50	93.75
....	18	207C	42.0	25.0	92.0	40.0	25.0	90.0	41.00	25.00	91.00
....	24	211	43.0	26.0	94.0	42.0	27.0	94.0	42.50	26.50	94.00
....	24	211C	39.0	25.0	89.0	39.0	27.0	91.0	39.00	26.00	90.00
....	27	214	40.0	25.0	90.0	42.5	27.0	94.5	41.25	26.00	92.25
....	27	214C	37.0	24.0	86.0	37.0	26.0	88.0	37.00	25.00	87.00
....	28	215	42.0	27.0	94.0	42.0	27.0	94.0	42.00	27.00	94.00
60	28	215C	37.0	25.0	87.0	38.0	26.0	89.0	37.50	25.50	88.00
....	May 2	216	41.0	26.0	92.0	40.5	26.0	91.5	40.75	26.00	91.75
58	2	216C	37.0	25.0	87.0	38.0	26.0	89.0	37.50	25.50	88.00
....	3	217	42.0	28.0	95.0	41.5	27.0	93.5	41.75	27.50	94.25
62	3	217C	37.0	25.0	87.0	40.0	26.0	91.0	38.50	25.50	89.00
....	8	220	41.0	27.0	93.0	42.0	27.0	94.0	41.50	27.00	93.50
62	8	220C	34.0	25.0	84.0	39.0	25.0	89.0	36.50	25.00	86.50
....	10	222	40.0	25.0	90.0	40.0	27.0	92.0	40.00	26.00	91.00
63	10	222C	37.0	25.0	87.0	40.0	26.0	91.0	38.50	25.50	89.00
....	15	225	40.0	26.0	91.0	42.0	28.0	95.0	41.00	27.00	93.00
64	15	225C	38.0	26.0	89.0	39.0	27.0	91.0	38.50	26.50	90.00
....	17	227	41.0	26.0	92.0	41.0	27.0	93.0	41.00	26.50	92.50
67	17	227C	35.0	24.0	84.0	37.0	25.0	87.0	36.00	24.50	85.50

[1] "C" in this column indicates raw-milk cheese.

TABLE 39.—*Scores of 53 pairs of raw and pasteurized cheese (lots 1A, 2A, 3A, and 4A) cured at Madison*—Continued.

LOT 3A, SCORED AUGUST 14, 1911.

Temperature of curing room 8 a. m.	Date made.	Cheese No.[1]	Scored by U. S. Bacr.			Scored by A. T. Bruhn.			Average.		
			Flavor.	Texture.	Total.	Flavor.	Texture.	Total.	Flavor.	Texture.	Total.
°F.	1911.										
67	May 22	230	43.0	27.0	95.0	41.5	26.5	93.0	42.25	26.75	94.00
....	22	230C	40.0	26.0	91.0	37.0	25.0	87.0	38.50	25.50	89.00
66	25	233	41.0	25.0	91.0	41.0	26.0	92.0	41.00	25.50	91.50
....	25	233C	38.0	25.0	88.0	36.0	25.0	86.0	37.00	25.00	87.00
....	29	234	42.0	27.0	94.0	42.0	27.0	94.0	42.00	27.00	94.00
....	29	234C	39.0	25.0	89.0	37.0	25.0	87.0	38.00	25.00	88.00
....	June 1	237	42.0	27.0	94.0	41.0	26.5	92.5	41.50	26.75	93.25
66	1	237C	35.0	25.0	85.0	38.0	26.0	89.0	36.50	25.00	87.00
....	2	238	40.0	26.0	91.0	41.0	26.5	92.5	40.50	26.25	91.75
66	2	238C	37.0	26.0	88.0	37.0	25.5	87.5	37.00	25.75	87.75
....	7	240	40.0	27.0	92.0	41.0	26.0	92.0	40.50	26.50	92.00
66	7	240C	33.0	25.0	83.0	37.0	26.0	88.0	35.00	25.50	85.50
....	9	242	39.0	27.0	91.0	41.5	26.0	92.5	40.25	26.50	91.75
70	9	242C	39.0	26.0	90.0	38.0	26.0	89.0	38.50	26.00	89.50
....	13	243	40.0	27.0	92.0	41.0	26.0	92.0	40.50	26.50	92.00
68	13	243C	38.0	25.0	88.0	38.0	25.0	88.0	38.00	25.00	88.00
....	15	245	41.0	27.0	93.0	41.5	27.0	93.5	41.25	27.00	93.25
66	15	245C	37.0	26.0	88.0	40.0	26.0	91.0	23.50	26.00	89.50
....	16	246	40.0	27.0	92.0	40.0	26.0	91.0	40.00	26.50	91.50
66	16	246C	40.0	26.0	91.0	39.0	27.0	91.0	39.50	26.50	91.00

LOT 4A, SCORED SEPTEMBER 18, 1911.

Temperature of curing room 8 a. m.	Date made.	Cheese No.[1]	Scored by U. S. Bacr. Flavor.	Texture.	Total.	Scored by A. T. Bruhn. Flavor.	Texture.	Total.	Average. Flavor.	Texture.	Total.
68	June 19	248	42.0	27.0	94.0	42.0	27.0	94.0	42.00	27.00	94.00
....	19	248C	40.5	26.0	91.5	40.0	26.5	91.5	40.25	26.25	91.50
68	21	250	40.0	26.0	91.0	41.0	26.5	92.5	40.50	26.25	91.75
....	21	250C	37.0	25.0	87.0	38.0	25.0	88.0	37.50	25.00	87.50
70	26	253	37.0	25.0	87.0	39.0	25.0	89.0	38.00	25.00	88.00
....	26	253C	35.0	25.0	85.0	35.0	26.0	86.0	35.00	25.50	85.50
70	27	254	41.0	27.0	93.0	41.0	27.0	93.0	41.00	27.00	93.00
....	27	254C	37.0	26.0	88.0	37.0	26.0	88.0	37.00	26.00	88.00
70	28	255	41.0	27.0	93.0	41.0	27.0	93.0	41.00	27.00	93.00
....	28	255C	35.0	25.0	85.0	37.0	25.5	87.5	36.00	25.25	86.25
72	July 3	258	40.0	27.0	92.0	40.5	26.5	92.0	40.25	26.75	92.00
....	3	258C	35.0	25.0	85.0	35.0	25.0	85.0	35.00	25.00	85.00
72	8	260	41.0	27.0	93.0	41.0	26.5	92.5	41.00	26.75	92.75
....	8	260C	37.0	25.0	87.0	36.0	25.0	86.0	36.50	25.00	86.50
73	10	261	40.0	25.0	90.0	39.5	26.0	90.5	39.75	25.50	90.25
....	10	261C	38.0	27.0	90.0	38.0	27.0	90.0	38.00	27.00	90.00
73	11	262	41.0	27.0	93.0	41.0	26.5	92.5	41.00	26.75	92.75
....	11	262C	37.0	26.0	88.0	37.0	25.5	87.5	37.00	25.75	87.75
72	12	263	40.0	26.0	91.0	40.0	26.0	91.0	40.00	26.00	91.00
....	12	263C	35.0	26.0	86.0	35.0	26.0	86.0	35.00	26.00	86.00

[1] "C" in this column indicates raw-milk cheese.

In 51 cases out of the 53 in the table the pasteurized-milk cheese received a higher average total score than the raw-milk cheese; but in two cases the raw-milk cheese scored one-fourth to one-half a point higher (Nos. 183 and 184). In the 51 cases just mentioned the differences in total score between pasteurized and raw milk cheese ranged from one-fourth of a point to 7 points and averaged 3.82 points. In four-fifths of these cases the difference in the score was over 2 points. In 49 of the 53 raw-milk cheeses the average score was below 92, while 39 of the 53 pasteurized-milk cheeses scored 92 or above. The distribution of the scores in each case is most clearly shown in figure 3.

It can readily be seen from figure 3 that 94 per cent (50 out of 53) of the pasteurized cheese scores lie between 91 and 95, a range of 4 points, while the same proportion (94 per cent) of the raw-milk cheese scores are quite uniformly distributed between 85 and 92, a range of 7 points.

The variation in quality of product from day to day is thus reduced nearly one-half by the new process. In scoring all of these cheeses the color and make-up were always marked perfect, and the cheeses were marked off only on flavor and texture. It is of interest therefore to consider the flavor and texture scores separately, in addition to the discussion of total scores given above.

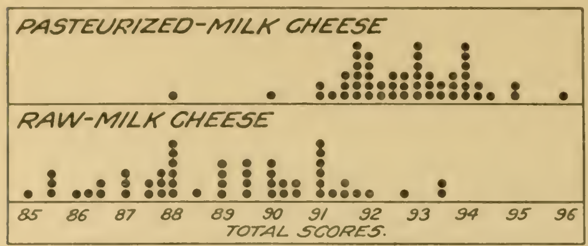

FIG. 3.—Distribution of total scores of pasteurized and raw milk cheese.

The average flavor score for all of the pasteurized cheese is 41.05 and for the raw-milk cheese 38.13. In 50 cases out of 53 the pasteurized-milk cheese has a higher average flavor score than the raw, in 2 cases the scores are equal, and in 1 case the pasteurized cheese is one-fourth point less than the raw.

In the 50 cases just mentioned the difference in the flavor score between the two makes of cheese ranged from 0.50 to 5.50 points, averaging 3.1 points. The difference was equal to or greater than 1.25 points in 47 out of the 50 cases, showing that the improvement in flavor through pasteurization was not only unquestionable, but also consistent. In 51 out of the 53 cases the pasteurized-milk cheese scored 40 or above for flavor, while 45 out of the 53 raw-milk cheese scored below 40 for flavor.

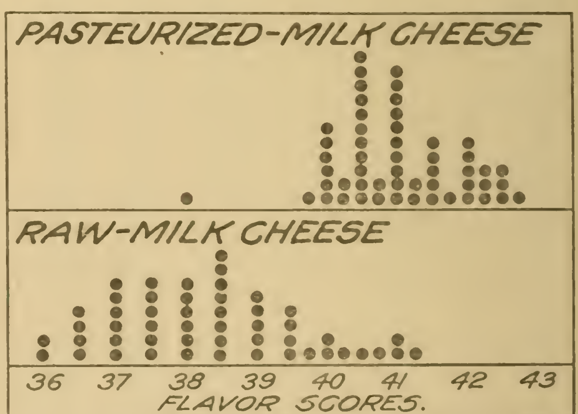

FIG. 4.—Distribution of flavor scores of pasteurized and raw milk cheese.

Figure 4 shows that 94 per cent (50 out of 53) of the pasteurized cheese flavor scores lie between 40 and 42½, a range of 2½ points; while the raw-milk cheese flavor scores are quite evenly distributed

over a range of 5 points (from 35 to 40 or 41). The range of variation is thus twice as great in the raw as it is in the pasteurized, showing that the daily variation of flavor is reduced about one-half by the new process.

The average texture scores show also some advantage for the new-process cheese. The average texture score on all of the pasteurized-milk cheese was 26.70, and on the raw-milk cheese 25.96.

In 40 cases out of 53 the pasteurized cheese scored higher than the raw, in five cases the scores were equal, and in 8 cases the pasteurized cheese scored 0.25 to 1.5 points (average 0.59 point) lower than the raw. Among the 40 cases just mentioned, the differences in texture score between the two makes ranged from 0.25 to 2 points, and averaged 1.09 points.

Figure 5 shows that 90 per cent (48 out of 53) of the pasteurized-milk cheese texture scores lie between 26 and 27.50, a range of 1.50 points; while 94 per cent (50 out of 53) of the raw-milk cheese scores are quite evenly distributed between 25 and 27, a range of 2 points, a distinct advantage in favor of the new process, both as to quality and uniformity of texture.

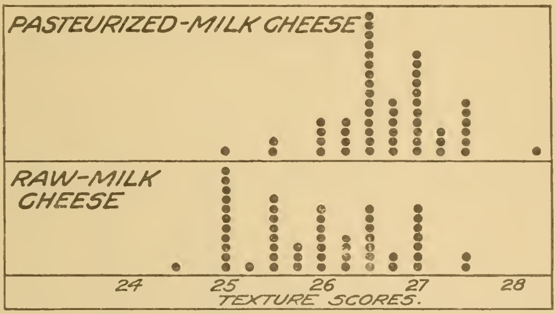

Fig. 5.—Distribution of texture scores of pasteurized and raw milk cheese.

CHEESE CURED IN THE SOUTH.

Lot 1B.—Four lots of cheese, lots 1B, 2B, 3B, and 4B, were shipped to New Orleans for storage, the first lot for two months and the other three for one month.

Lot 1B consisted of 25 pairs of cheese which were made on 25 days between February 23 and April 18, at Madison, and shipped to New Orleans April 29, arriving May 9. They were stored there until July 3, and then shipped back to Madison where they were scored separately on July 17, 1911, by Messrs. U. S. Baer and A. T. Bruhn. The temperatures at New Orleans given below are taken from the United States Weather Bureau monthly meteorological summaries. The average daily mean for May was 75.8°, with temperature on different days varying from 60 to 96. For June the average daily mean was 83.2°, with temperature on different days varying from 70 to 98. The quality of both the raw and pasteurized cheese after returning from New Orleans was very poor, as shown by the scores of the judges and by letters from dealers to whom they were afterwards sold at a

reduced price. The average score of the 25 pasteurized-milk cheeses was 85.10 and of the 25 raw-milk cheeses 83.34, a difference of 1.76 points. In 17 cases out of 25 the pasteurized-milk cheese scored higher, in 3 cases equal to, and in 5 cases less than the raw-milk cheese. (See Table 40.) The highest average score given to any cheese in the lot was 90.5 and the lowest 78.50. The scores are shown in Table 40.

TABLE 40.—*Scores of 25 pairs of raw and pasteurized cheeses (lot 1B) cured for two months at New Orleans.*

Date made.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
1911.				
Feb. 23	171	82	80	81
23	171C	87	87	87
24	172	83	79	81
24	172C	85	81	83
27	173	87	90	88.5
27	173C	85	86	85.5
28	174	90	85	87.5
28	174C	83	85	84
Mar. 1	175	86	87	86.5
1	175C	83	84	83.5
2	176	86	88	87
2	176C	83	84	83.5
3	177	88	84	86
3	177C	88	85	86.5
7	178	85	86	86
7	178C	86	85	85.5
8	179	91	90	90.5
8	179C	85	83	84
9	180	86	88	87
9	180C	85	85	85
10	181	90	88	89
10	181C	85	85	85
13	182	80	80	80
13	182C	80	80	80
14	183	79	79	79
14	183C	87	84	85.5
15	184	85	84	84.5
15	184C	85	82	83.5
16	185	85	89	87
16	185C	85	85	85
17	186	80	80	80
17	186C	80	80	80
20	187	79	80	79.5
20	187C	79	80	79.5
21	188	77	80	78.5
21	188C	80	80	80
22	189	86	83	84.5
22	189C	80	80	80
Apr. 5	198	92	89	90.5
5	198C	89	81	85
7	200	86	87	86.5
7	200C	82	85	83.5
11	202	85	88	86.5
11	202C	83	84	83.5
13	204	89	87	88
13	204C	84	84	84
17	206	89	86	87.5
17	206C	83	81	82
18	207	85	86	85.5
18	207C	83	84	83.5

[1] "C" in this column indicates raw-milk cheese.

It can be seen that storage for so long a period as two months in New Orleans, at such temperatures, can not be practiced with either raw or pasteurized cheese without great loss of quality; and that of the two lots, the pasteurized was somewhat the better when taken out of storage. On account of the unmarketable quality of both lots of cheese when scored it appears unnecessary to give the detailed score and criticisms as to flavor and texture.

Lots 2B, 3B, and 4B.—These lots were stored at New Orleans for one month each during parts of June, July, August, and September, 1911. The mean daily temperature during this period averaged 83.2° for June, 80.2° for July, 81.8° for August, and 82.6° for September. In lot 2B the 9 pasteurized-milk cheeses received an average total score of 90.44, and the raw-milk cheese of 85.56. The pasteurized was better in every case, and on the average 4.88 points better.

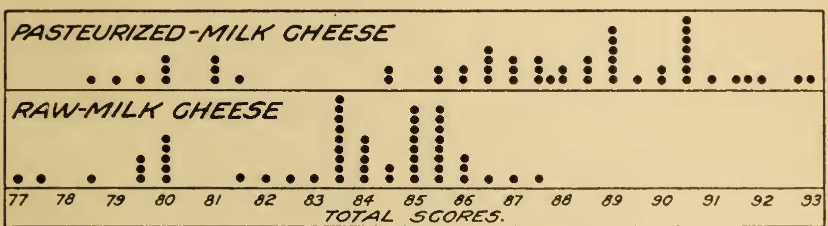

FIG. 6.—Distribution of total scores of pasteurized and raw milk cheese.

In lot 3B the 10 pasteurized-milk cheeses scored the highest in every case, the average being 7.7 points higher. The average score of the pasteurized was 90.30, and of the raw 82.60.

In lot 4B the 10 pasteurized-milk cheeses scored the highest in every case but one, and averaged 85.62, while the 10 raw-milk cheeses averaged 82.10, a difference of 3.52 points.

From the results shown in Tables 40 and 41 and in figure 6, it is clear that after storage in the South the pasteurized-milk cheese came out better in quality than the raw-milk cheese made from the same milk. It is not intended to suggest that cheese could be shipped to the Southern States with the express intention of storing it for one month before it is sold, but it is clear that during the few days or weeks necessarily elapsing after market cheese reaches its destination in the South and before it is eaten, the pasteurized-milk cheese is less likely to undergo serious deterioration than the raw-milk cheese.

TABLE 42.—*Scores of 29 pairs of raw and pasteurized cheeses (lots 2B, 3B, and 4B) cured for one month at New Orleans.*

LOT 2B, SCORED JULY 17, 1911, AT MADISON.

Date made.	Mean temperature at New Orleans.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
1911.	*°F.*				
Apr. 24	46	211	90	88	89
24	....	211C	85	86	85.5
27	60	214	92	90	91
27	....	214C	85	86	85.5
28	55	215	93	90	91.5
28	....	215C	85	84	84.5
May 2	66	216	90	88	89
2	....	216C	85	86	85.5
3	60	217	91	89	90.0
3	....	217C	85	85	85
8	71	220	90	87	88.5
8	....	220C	85	58	85
10	73	222	92	94	93
10	....	222C	88	87	87.5
15	76	225	89	91	90
15	....	225C	87	85	86
17	76	227	92	92	92
17	....	227C	86	85	85.5

LOT 3B, SCORED AUG. 14, 1911, AT MADISON.

May 22	78	230	89	88	88.5
22	....	230C	83	84	83.5
25	82	233	90	88	89
25	....	233C	79	80	79.5
29	84	234	91	90	90.5
29	....	234C	83	82	82.5
June 1	86	237	91	90	90.5
1	....	237C	80	81	80.5
2	85	238	91	90	90.5
2	....	238C	85	82	83.5
7	85	240	92	89	90.5
7	....	240C	80	79	79.5
9	87	242	93	92.5	92.75
9	....	242C	82	81	81.5
13	88	243	92	90.5	91.25
13	....	243C	86	85	85.5
15	88	245	90	91	90.5
15	....	245C	87	85	86
16	86	246	89	89	89
16	....	246C	86	82	84

LOT 4B, SCORED SEPT. 18, 1911, AT MADISON.

June 19	76	248	88.5	87	87.75
19	....	248C	83	85	84
21	74	250	81	82	81.5
21	....	250C	85	85	85
26	80	253	87	88	87.5
26	....	253C	87	85	86
27	82	254	89	89	89
27	....	254C	76	78	77
28	80	255	80	80	80
28	....	255C	78	77	77.5
July 3	82	258	85	86	85.5
3	....	258C	82	85	83.5
8	79	260	88	88	88
8	....	260C	86	83	84.5
10	82	261	62	80	81
10	....	261C	79	78	78.5
11	82	262	90	89	89.5
11	....	262C	85	85	85
12	79	263	87	86	86.5
12	....	263C	80	80	80

[1] "C" indicates raw-milk cheese.

Lots 3C and 4C.—These two additional lots were stored for one month in the South and subsequently scored at Madison. In lot 3C the 10 pasteurized cheeses averaged 91 and the 10 raw-milk cheeses 84.85, as shown in Table 42. In every case the pasteurized cheese scored higher than the raw. In Lot 4C, the 10 pasteurized averaged 87.82 in total score, and the 10 raw-milk cheeses, 85.07, and in every case but one the pasteurized scored higher than the raw. All but two of these 40 cheeses scored below 92 and most of them were unsalable at full price, after storage as described. The temperature inside of the storage warehouse was not recorded.

TABLE 42.—*Scores of 20 pairs of raw and pasteurized milk cheese (lots 3C and 4C) stored one month in the South and scored at Madison.*

LOT 3C, STORED ONE MONTH AT COLUMBUS, GA., AND SCORED AT MADISON, AUG. 14, 1911.

Date made.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
1911.				
Apr. 22	230	90	90	90
22	230C	87	86	86.5
25	233	90	89½	89.75
25	233C	85	84	84.5
29	234	94	94	94
29	234C	91	87	89
June 1	237	92	89	90.5
1	237C	85	83	84
2	238	90	91	90.5
2	238C	84	85	84.5
7	240	92	91	91.5
7	240C	78	79	78.5
9	242	91	93	92
9	242C	85	87	86
13	243	Lost.	Lost.	Lost.
13	243C	85	82	83.5
15	245	91	90	90.5
15	245C	89	84	86.5
16	246	90	90½	90.25
16	246C	88	83	85.5

LOT 4C, STORED ONE MONTH AT NEW ORLEANS, AND SCORED AT MADISON, SEPT. 18, 1911.

Date made.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
1911.				
June 19	248	90	89½	89.75
19	248C	85	86	85.5
21	250	88	88	88
21	250C	85	85	85
26	253	86	87	86.5
26	253C	86	85½	85.75
27	254	90	89½	89.75
27	254C	80	83	81.5
28	255	89½	89½	89.5
28	255C	83	85	84
July 3	258	87	88	87.5
3	258C	86	86	86
8	260	89	90	89.5
8	260C	87	86	86.5
10	261	83	84	83.5
10	261C	87	86	86.5
11	262	85	85	85
11	262C	85	85	85
12	263	90	88½	89.25
12	263C	85	85	85

[1] "C" indicates raw-milk cheese.

CHEESE CURED IN WARM ROOM AT MADISON.

Lots 3D and 4D.—These lots of cheese were stored in a warm room at Madison where the temperature ranged from 70° to 80°, occasionally going up to 85°, during the months of July, August, and September, 1911. In lot 3D the pasteurized cheese scored higher than the raw-milk cheese in every case, averaging 90.55 to total score, while the raw-milk cheese averaged 83.75. In lot 4D the pasteurized cheese scored higher than the raw in every case but one, averaging 90.52, while the raw-milk cheese averaged 86.15, as shown in Table 43.

TABLE 43.—*Scores of 20 pairs of raw and pasteurized milk cheese (lots 3D and 4D) stored in warm room at Madison.*

LOT 3D, SCORED AUG. 14, 1911.

Date made.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
1911.				
May 22	230	87	87	87
22	230C	85	86	85.50
25	233	90	89½	89.75
25	233C	81	80	80.50
29	234	93	94	93.50
29	234C	85	85	85
June 1	237	94	94	94
1	237C	80	80	80
2	238	90	91	90.5
2	238C	85	86	85.5
7	240	94	94	94
7	240C	79	79	79
9	242	92	92½	92.25
9	242C	85	85	85
13	243	90	89	89.5
13	243C	85	86	85.5
15	245	87	88	87.5
15	245C	85	86	85.50
16	246	88	87	87.5
16	246C	87	85	86

LOT 4D, SCORED SEPT. 18, 1911.

Date made.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
June 19	248	91	91½	91.75
19	248C	85	85	85
21	250	86	86	86
21	250C	86	85	85.50
26	253	88	88	88
26	253C	85	86	85.5
27	254	91	92	91.5
27	254C	80	82	81
28	255	92	92½	92.25
28	255C	89½	89½	89.5
July 3	258	92	92	92
3	258C	87	86	86.5
8	260	91	92	91.5
8	260C	86	86½	86.25
10	261	85	85	85
10	261C	89	87	88
11	262	94	94	94
11	262C	86	88	87
12	263	93	93	93
12	263C	86	89	87.5

[1] "C" indicates raw-milk cheese.

CHEESE CURED IN COLD STORAGE.

Lot 4E.—Since much of the cheese made by the ordinary process is put into cold storage at about 34°, and most cheese dealers have cold-storage warehouses, a study was begun of the effect of cold storage on pasteurized-milk cheese. The milk supply was so short at the time that raw-milk cheese could be made on only a few days. Six or seven pasteurized-milk cheeses were made in one vat each day and placed in the curing room at Madison, and single cheeses were shipped to a cold-storage warehouse at Waterloo, Wis., at different ages. After about three months the cheese was all shipped back to Madison in one consignment and examined by the judges. One cheese from each day's make was kept at Madison during the entire period.

TABLE 44.—*Scores of pasteurized and raw milk cheese (lot 4E) put into cold storage at different ages and scored Oct. 30, 1911.*

Date made.	Cheese No.[1]	Age when stored.	Scored by U. S. Baer.			Scored by A. T. Bruhn.			Average score.		
			Flavor.	Texture.	Total.	Flavor.	Texture.	Total.	Flavor.	Texture.	Total.
1911.											
July 20	264.1	....	42.00	28.00	95.00	42.50	27.00	94.50	42.25	27.50	94.75
20	264.2	1 day....	41.00	26.50	92.50	40.50	27.00	92.50	40.75	26.75	92.50
20	264.3	1 week..	40.00	26.00	91.00	40.50	27.00	92.50	40.25	26.50	91.75
20	264.4	2 weeks.	41.00	28.00	94.00	41.00	27.50	93.50	41.00	27.75	93.75
20	264.5	4 weeks.	41.00	28.00	94.00	42.00	28.00	95.00	41.50	28.00	94.50
20	264.6	6 weeks.	41.00	28.00	94.00	42.00	27.50	94.50	41.50	27.75	94.25
20	265.1	....	41.00	27.00	93.00	41.00	26.50	92.50	41.00	26.75	92.75
21	265.2	1 day....	40.00	27.00	92.00	41.00	26.50	92.50	40.50	26.75	92.25
21	265.3	1 week..	42.00	28.00	95.00	42.00	28.00	95.00	42.00	28.00	95.00
21	265.4	2 weeks.	40.00	27.00	92.00	40.00	27.00	92.00	40.00	27.00	92.00
21	265.5	4 weeks.	40.00	27.00	92.00	40.00	27.00	92.00	40.00	27.00	92.00
21	265.6	4 weeks.	40.00	27.00	92.00	41.00	27.00	93.00	40.50	27.00	92.50
25	265.7	6 weeks.	41.00	28.00	94.00	42.00	27.00	94.00	41.50	27.50	94.00
25	267.1	....	41.00	28.00	94.00	42.00	27.00	94.00	41.50	27.50	94.00
25	267.2	1 day....	40.00	26.00	91.00	40.00	26.00	91.00	40.00	26.00	91.00
25	267.3	1 week..	41.50	27.00	93.00	41.50	27.50	94.00	41.50	27.25	93.75
25	267.4	2 weeks.	40.00	27.00	92.00	41.00	27.00	93.00	40.50	27.00	92.50
25	267.5	4 weeks.	41.00	27.00	93.00	40.50	27.00	92.50	40.75	27.00	92.75
25	267.6	6 weeks.	42.00	27.00	94.00	42.00	27.50	94.50	42.00	27.25	94.25
25	267C1	....	36.00	26.00	87.00	36.00	26.50	87.50	36.00	26.25	87.25
25	267C2	1 day....	38.00	27.00	90.00	39.00	27.00	91.00	38.50	27.00	90.50
25	267C3	2 weeks.	38.00	27.00	90.00	38.50	27.00	90.50	38.25	27.00	90.25
27	269.1	....	40.00	27.00	92.00	41.00	26.50	92.50	40.50	26.75	92.25
27	269.2	1 day....	40.00	27.00	92.00	40.50	26.50	92.00	40.25	26.75	92.00
27	269.3	1 week..	40.00	27.00	92.00	40.50	26.50	92.00	40.25	26.75	92.00
27	269.4	2 weeks.	41.00	27.00	93.00	40.00	26.50	91.50	40.50	26.75	92.25
27	269.5	4 weeks.	41.00	27.00	93.00	42.00	27.00	94.00	41.50	27.00	93.50
27	269.6	6 weeks.	42.50	28.00	95.50	42.50	27.50	95.00	42.50	27.75	95.25
27	269C1	2 weeks.	34.00	23.00	82.00	32.00	25.00	82.00	33.00	24.00	82.00
Aug. 1	272.1	....	35.00	23.00	83.00	36.00	25.00	86.00	35.50	24.00	84.50
1	272.2	1 day....	36.00	25.00	86.00	36.00	25.00	86.00	36.00	25.00	86.00
1	272.3	1 week..	37.00	25.00	87.00	39.00	24.00	88.00	38.00	24.50	87.50
1	272.4	2 weeks.	38.00	25.00	88.00	38.00	25.00	88.00	38.00	25.00	88.00
1	272.5	4 weeks.	35.00	25.00	85.00	36.00	24.00	85.00	35.50	24.50	85.00
1	272.6	6 weeks.	37.00	24.50	86.50	38.00	25.00	88.00	37.50	24.75	87.25
8	276.1	....	37.00	25.00	87.00	39.00	26.00	90.00	38.00	25.50	88.50
8	276.2	1 day....	40.00	26.00	91.00	40.00	26.00	91.00	40.00	26.00	91.00
8	276.3	1 week..	40.00	25.00	90.00	39.50	25.50	90.00	39.75	25.25	90.00
8	276.4	2 weeks.	40.00	24.00	89.00	39.00	25.00	89.00	39.50	24.50	89.00
8	276.5	4 weeks.	40.00	27.00	92.00	39.50	26.50	91.00	39.75	26.75	91.50
22	283.1	....	41.00	27.00	93.00	41.50	26.50	93.00	41.25	26.75	93.00
22	283.2	1 day....	40.00	26.00	91.00	40.50	26.00	91.50	40.25	26.00	91.25
22	283.3	1 week..	42.00	27.00	94.00	41.00	27.00	93.00	41.50	27.00	93.50
22	283.4	2 weeks.	40.50	27.00	92.50	41.00	26.50	92.50	40.75	26.75	92.00
22	283.5	4 weeks.	42.00	27.00	94.00	41.50	27.00	93.50	41.75	27.00	93.50
22	283.6	....	42.00	27.00	94.00	42.00	26.50	93.50	42.00	26.75	93.75

[1] "C" in this column indicates raw-milk cheese.

In every case the pasteurized-milk cheese put into cold storage at the age of one day was criticized by the judges as being flat, low, and not developed in flavor, and the texture was described as curdy, new, not broken down, not cured, etc. They received an average score of 90.84, as shown in Table 44.

The cheeses put into cold storage at the age of one week received an average score of 91.93. They were found to be well cured, and they had less mold on the surface (practically none), both when put into storage and when taken out, than any of the later lots. The cheeses put into storage at two weeks, four weeks, and six weeks of age were given average scores of 91.36, 91.82, and 91.46, respectively, while those kept at Madison for the entire period scored 91.39.

So far as this short series indicates, there is no objection to putting pasteurized-milk cheese into storage at 34°, at the age of one week, immediately after paraffining. It was planned, however, to make a more extensive trial of the use of cold storage for pasteurized-milk cheese during the season of 1912.

EXCEPTIONAL DIFFERENCES BETWEEN THE RAW AND PASTEURIZED MILK CHEESE.

It is of interest to collect in one place all of the cases recorded in the tables where the pasteurized-milk cheese was scored lower than the raw, in order if possible to locate the cause for such difference.

TABLE 45.—*Summary of cases in which raw-milk cheese scored higher than pasteurized.*

Lots 1A, 2A, 3A, 4A.		Lots 1B, 2B, 3B, 4B.		Lots 3C, 4C.		Lots 3D, 4D.	
Cheese No.[1]	Total Score.	Cheese No.[1]	Total Score.	Cheese No.[1]	Total Score.	Cheese No.[1]	Total Score.
....	....	171	81.00	....	....	....	....
....	....	[2] 171C	87.00	....	....	....	....
172	91.75	172	81.00	....	....	....	....
172C	89.50	[2] 172C	83.00	....	....	....	....
177	91.75	177	86.00	....	....	....	....
177C	89.00	[2] 177C	86.50	....	....	....	....
183	91.25	183	79.00	....	....	....	....
[2] 183C	91.75	[2] 183C	85.50	....	....	....	....
184	92.00	184	84.50	....	....	....	....
[2] 184C	92.75	184C	83.50	....	....	....	....
188	94.50	188	78.50	....	....	....	....
188C	90.50	[2] 188C	80.00	....	....	....	....
250	91.75	250	81.50	250	88.00	250	86.00
250C	87.50	[2] 250C	85.00	250C	85.00	250C	85.50
261	90.25	261	81.00	261	83.50	261	85.00
261C	90.00	261C	78.50	[2] 261C	86.50	[2] 261C	88.00

[1] "C" indicates raw-milk cheese.
[2] These are the cases in which the raw-milk cheese scored higher than the pasteurized. The other scores of duplicate cheese in the other lots are given for comparison.

The fact that pasteurized and raw cheese from the same milk may occasionally score exactly alike or nearly alike would appear to indicate that where the milk supply is excellent the quality of cheese produced is not improved by the new process. With so small a difference in score as half a point, occurring in No. 184 in lot A and No.

177 in lot B, it is doubtful whether there was any difference between the two cheeses which could be ascribed with certainty to the effect of the pasteurization process.

The most adverse criticism on the process that can be based upon the 10 cases tabulated above is the following: It is entirely possible that some harmful bacteria or their enzyms which are occasionally present in dirty milk may not be destroyed by the pasteurization process and that such infections damage the quality of pasteurized-milk cheese as well as raw-milk cheese. In this year's work it has been noticed that on a few occasions when the raw milk was very ripe the quality of cheese produced, even after pasteurization, was not so good as from milk of fairly good quality. For example: The poorest pasteurized-milk cheese in Table 45 is No. 261, and the milk used for making this was of 0.28 per cent acidity before pasteurization. In Table 44, showing the scores of cheese shipped to cold storage, Nos. 272 and 276 are the poorest in quality and these were made from milk which titrated 0.275 and 0.31 per cent acidity, respectively, before pasteurization. Of course such milk should not be accepted at any cheese factory.

No claim is made that the pasteurization process is a cure for all the troubles of the cheese factory, or that it reduces the responsibility resting on factory patrons to improve the sanitary quality of their milk. It would, in fact, be most unfortunate if any process could be used for making cheese, or any other article of food, which would relieve the milk producer or the factory man of the necessity for cleanliness.

SUMMARY OF DISCUSSION OF SCORES.

The scores of lots 1B, 2B, 3B, and 4B, 3C and 4C, and 3D and 4D all show that cheese, either raw or pasteurized, stored for one or two months at about 80° are often seriously injured, so as to be unsalable at the ruling market price. The pasteurized cheese came out of such storage better in quality than the raw-milk cheese in about 90 per cent of all the cases observed. It is clear that pasteurized-milk cheese is better suited to stand exposure to high temperature than raw-milk cheese. This fact may find useful application in two ways: While it is never advisable to store market cheese for any great length of time in the South, yet several days or weeks may often elapse before cheese shipped South is finally sold to the consumer, and it appears that pasteurized-milk cheese should stand this exposure with less damage in quality than raw-milk cheese. It is likely, too, that pasteurized-milk cheese can be cured at ordinary curing-room temperatures below 70° in Wisconsin without the use of ice or mechanical refrigeration, thus avoiding part of the expense for cold storage. The quality of the 53 raw-milk cheeses in lots 1A, 2A, 3A, and 4A, cured at 60° to 73° at Madison, is represented by the

average total score of 89.09, and would no doubt have been greatly improved if the cheese had been cured in cold storage. In 51 cases out of 53 the pasteurized-milk cheese in these lots scored higher than the raw, on the average 3.8 points higher, the average total score of the pasteurized being 92.75 points, which indicates that cold storage for the pasteurized cheese was not necessary.

In a short series of cheese placed in cold storage at 34° F. at different ages, it was found that those stored at the age of one day were curdy and uncured at the age of three months, while those placed in storage at the age of one week were free from this fault and scored as high, even a little higher, and showed less mold on the surface than those put in storage when older than one week. From this it appears that pasteurized-milk cheese can be safely put in cold storage at the age of one week immediately after paraffining. It was planned to try cold storage with both raw and pasteurized-milk cheese during 1912.

THE DEMAND FOR PASTEURIZED-MILK CHEESE.

One of the objects of the work during 1909, 1910, and 1911 was to sell the cheese to consumers as widely as possible, and learn whether it would meet with favor and continued demand. It was felt necessary thus to establish its suitability for the market before recommending cheese makers to take up the new process.

The amount of pasteurized-milk cheese sold each year was limited by the output of the factory, it being impossible to secure a larger supply of milk. Much more cheese could have been sold to the same purchasers, and doubtless to others, if we had had the cheese to sell. In nearly all cases the cheese was sold at the current price ruling on the Plymouth cheese board, f. o. b. Madison without discount. During 1910, 4,815½ pounds of pasteurized-milk cheese valued at $711.16 were sold to 19 representative grocery stores, hotels, restaurants, and delicatessen stores in Madison, Wis. The total number of such sales was 137 during the season. Nearly every purchaser reordered it several times, and three of the leading retailers reordered it 15, 20, and 49 times, respectively, during the season. The average price paid for all of this cheese was 14¾ cents per pound. During 1909, 1910, and 1911, 41 shipments of pasteurized-milk cheese weighing 10,126 pounds in all and valued at $1,382.93 were sent to 27 leading cheese dealers, including a few retail stores, at New York, Boston, Philadelphia, Chicago, St. Louis, Minneapolis, and San Francisco, and at various Wisconsin points outside of Madison, including Plymouth, Sheboygan, Fond du Lac, Marshfield, Richland Center, Waterloo, and Milwaukee. Samples of the cheese were also shipped to experiment station workers in the leading dairy States for an examination.

OPINIONS OF PURCHASERS.

No written opinions were asked from dealers in Madison handling the pasteurized-milk cheese, neither were they urged to purchase a second time. The university delivery wagon making two trips daily among retail stores took such orders as were given. The fact that a dealer bought this make of cheese only once may be due to a variety of causes, such, for example, as business relations with other wholesale cheese dealers in the city. The fact that several of the leading grocers sold this cheese continuously for several months and repurchased it every week or oftener, and always without reporting any complaint from consumers, is taken to indicate that it was satisfactory to the retail trade of this city.

An effort was made to obtain a written opinion from every firm outside of Madison to whom the cheese were sold. It was usually impossible to send many shipments to a single purchaser, because it was desired to distribute the available supply of cheese as widely as possible.

The letters received from dealers outside of Madison show that all except a very few found the cheese to be entirely satisfactory, and salable at the full market price. Here again the occasional disapproval of a cheese may be due to an oversupply in the buyer's warehouse, or other causes than the quality of the cheese iteslf. It is interesting to note that pasteurized-milk cheese shipped to two firms who apparently disliked it was the same day's make as others shipped on the same date to three other firms who praised their quality and pronounced them satisfactory. In every case dealers were informed that the cheese "was made by special process, which we are trying at Madison, by which it is hoped that cheese of cleaner flavor and greater uniformity can be obtained." In no case were dealers informed as to the nature of the process or that the milk was pasteurized. The purpose was to excite the dealers' interest and secure careful examination of the cheese, unqualified by any prejudice for or against pasteurization.

The very general expression of approval of the product in the letters from dealers and experiment stations appears to warrant further trial of the method on a larger scale than heretofore.

THE EXTRA COST OF MAKING PASTEURIZED-MILK CHEESE.

While it has been shown that an increased yield of cheese is obtained there are also additional costs, which must be charged against the cheese made by this method. Such costs will include the interest on investment, and depreciation, of a pasteurizer, cooler, and receiving vat, a charge for the hydrochloric acid used and for the expense of steam heat and power for pumping water for cooling the pasteurized milk, and for running the pasteurizer.

Preliminary estimates, based upon available data, seem to indicate that the extra cost of making pasteurized-milk cheese is less than the additional value of the cheese, leaving a net profit from the use of the process, as compared with the regular factory process. Since the steam and water supplies used in the work at Madison were drawn from the general service pipes of the Wisconsin Agricultural Experiment Station it was impossible to determine these items of cost with exactness.

In order to ascertain precisely what the charges for steam heat, power, etc., are at an average cheese factory in Wisconsin, a complete outfit for making pasteurized-milk cheese will be set up at a country cheese factory, easily accessible from Madison, and operated by an experienced and successful cheese maker. Cheese will be made there by both the regular factory method and by the new method in order to ascertain more fully the cost of making, the increased yield, and the market value of pasteurized-milk cheese.

FURTHER TRIALS OF THE NEW PROCESS IN CHEESE FACTORIES.

The results described in this bulletin appear to indicate that the new method of cheese making is an improvement over the regular process now commonly used. Working with the milk supply available at Madison, the new method is unquestionably an improvement over the old. It is a fact well known to cheese makers, however, that the milk supplies found at different factories do not always behave alike in the cheese vat, so that the old process must frequently be modified to suit the conditions encountered in different localities. It remains, therefore, to test the new method at several factories in different cheese-making districts before it can be recommended for use generally. Cheese makers are advised to await the publication of results of further trials before undertaking to use the new method on a commercial scale.

It is hoped that the new method will receive careful attention and criticism by such cheese experts at experiment stations in different parts of the country as may be able to give it a trial. The authors will be glad to correspond with any one interested and to aid in such trials so far as circumstances permit.

SUMMARY.

PRELIMINARY AND COMPARATIVE WORK WITH THE OLD AND NEW METHODS.

The continued improvement of the cheese-making industry calls for more economical factory management. Large, well-equipped factories should replace many of the small, poorly supported factories of the present time.

To enable cheese factories to handle milk from larger areas of territory, and for other reasons also, a new method of cheese making is needed by means of which milk of variable quality from many farms can (1) be brought into practically uniform condition for cheese making at the factory, and (2) can be made up into cheese in a uniform, routine manner daily without variations of time or method of handling; also (3) cheese of greater uniformity should be produced, and (4) the losses in yield and quality of cheese due to defective milk, now common in factories, should be avoided.

During the years 1905 and 1906 experimental cheese was made without starter, adding in its place to the raw milk some commercial acid, as hydrochloric acid or other kinds. The method of adding the acid to milk was perfected, and a two weeks' trial of the process was finally made in a commercial factory at Muscoda, Wis. It was shown clearly that the addition of hydrochloric acid to milk in a cheese factory is entirely practicable and that the quality of the cheese is not in any way injured by such addition, but it was also found that the quality of cheese obtained from overripe or tainted milk was no better than by the use of the ordinary factory methods. Therefore, there was no reason for recommending the use of hydrochloric acid to cheese makers at that time.

Most of the defects observed in cheese-factory milk are of bacterial origin, and in other branches of the dairy industry pasteurization is successfully employed to overcome these faults. The desirability of pasteurizing milk for cheese making, if possible, has often been pointed out.

In 1907 a few lots of milk were pasteurized in a discontinuous pasteurizer and acidulated with hydrochloric acid, and the cheese obtained was such as to demonstrate the importance of further study.

In 1908 equally good results were obtained by use of the continuous pasteurizer. A temperature of 160° to 165° was decided upon as being sufficiently high to effectually check bacterial action in milk for cheese-making purposes. Bacterial counts showed that over 99 per cent of the total bacterial content of the milk was destroyed at this temperature. The use of higher temperatures was shown to be objectionable on account of the effect upon the quality of the cheese.

In 1909 cheese was made almost daily both by the regular factory process and by the new process from pasteurized milk. The regular milk supply was thoroughly mixed each day and divided into two lots for the two different processes. The cheese made from pasteurized milk was found after curing to be cleaner in flavor and superior in texture to the raw-milk cheese. The difference was more marked the poorer the quality of the milk supply. Many of the details of the process were studied and improved.

In 1910 the making of cheese by the two methods for comparison was continued, and the entire output of pasteurized-milk cheese was sold to retail grocers, mostly in the city of Madison, in order to determine how this cheese would suit the trade. The cheese met with ready and continued sale. It was noticed also that the yield of cheese was, regularly, somewhat greater by the new process than by the old.

In 1911 better facilities were provided for weighing large quantities of milk and cheese quickly and accurately, and the yields of cheese obtained from raw and pasteurized milk were carefully determined. The accuracy of the experimental methods was such that in making duplicate vats of cheese from pasteurized milk the yields differed by only 0.58 per cent on the average. A greater yield of cheese was always obtained from the pasteurized milk than from raw milk, and during the year 1911 the average gain in yield of green cheese was 5.37 per cent. However, the green pasteurized-milk cheese shrank a little more than the raw-milk cheese, so that when paraffined the average gain in yield from pasteurized milk was 4.76 per cent. After curing cheese at 60° to 70° F. for about 100 days, the gain in yield of pasteurized-milk cheese over the raw was 4.22 per cent.

SOME ADVANTAGES FROM THE USE OF PASTEURIZED MILK AND HYDROCHLORIC ACID.

The average loss of fat in whey from pasteurized-acidulated milk is about 0.17 per cent measured at the time the whey is drawn from the vat. This is less than half the loss in average factories using raw milk. The total loss of fat in whey and drippings from vat and press, using pasteurized milk with acid, averaged 1.58 per cent of the weight of the cheese, or less than one-half of the usual loss in handling raw milk.

In addition to this saving of fat, it is found that a somewhat larger proportion of moisture can be incorporated in pasteurized-milk cheese than in ordinary cheese, without damage to the quality. The gain in the yield of pasteurized-milk cheese is due partly to fat and partly to moisture.

Scores and criticisms made by competent cheese judges show that the pasteurized-milk cheese varies less in quality and averages better by 3.7 points of total score than the raw-milk cheese made from portions of the same milk supply. In 96 per cent of all cases the pasteurized-milk cheese scored higher than the raw-milk cheese.

Duplicate sets of cheese were cured at New Orleans for one month at 70° to 83° (monthly average figures during the summer), and here the raw milk lost more in weight than the pasteurized, so that the average gain in yield of pasteurized over raw rose to 6.21 per cent.

From other cheese cured at Madison on tin pans in a warm room, it was learned that the raw-milk cheese lost considerable amounts of fat at 75° to 85° while the pasteurized-milk cheese lost none.

Storage for a month at an average temperature of 75° to 80° at New Orleans is not recommended for any cheese, yet it was found that pasteurized-milk cheese averaged 3 to 8 points better in total score after such storage than raw-milk cheese.

Since pasteurized-milk cheese can be cured without injury at 70°, it is likely that in most cases the expense of cold storage for this cheese can be avoided.

Pasteurized-milk cheese can be put into cold storage at 34° at the age of one week and possibly earlier without injury. The earlier the cheese can be put in storage, if this is done at all, the greater will be the gain in yield by the new process. It is planned to study the cold storage of this cheese further.

During 1910–1911 about $2,100 worth of pasteurized-milk cheese was sold to about 50 dealers, both wholesale and retail, in various large cities from New York to San Francisco. The cheese sold readily for the ruling market prices and often above. Very few dealers offered any objections to them and several wished to buy them regularly. A good many were sold throughout the South by dealers. In general, the cheese passed through the market without exciting special comment, selling for full price and giving satisfaction. They were not labeled or marked except with a number for purposes of identification. There appears to be no reason why pasteurized-milk cheese can not be sold regularly in any market with entire satisfaction, excepting possibly to the limited trade that demands very high-flavored cheese.

OUTLINE OF THE NEW METHOD.

In the method here described a principle is applied to the cheese-making process which has already been found useful in many other lines of manufacture, namely:

The raw material, milk, is first treated by a preparatory process to bring it into uniform condition before it enters the manufacturing process proper. Material of uniform quality thus prepared is made up into the finished product by a uniform routine process without daily variations of the time schedule or other details, and the product is more uniform in quality, has better keeping qualities, etc., than the product obtained by the older process.

The difficulties met with hitherto in making American Cheddar cheese from pasteurized milk are:

First. That heated milk coagulates poorly with rennet; and

Second. The curd when obtained does not expel moisture precisely as a raw-milk curd does, and this effect is more marked the

higher the temperature of pasteurization. The quality and behavior of pasteurized-milk curd suggest that it lacks the acid which is normally produced in raw-milk curds by the action of bacteria on milk sugar.

The first of these difficulties, but not the second, can be overcome by adding calcium-chlorid solution to pasteurized milk. This method has been tried experimentally, but is not recommended for use in American cheese factories. Both difficulties, however are overcome by adding an acid, preferably hydrochloric, to the pasteurized milk. Hydrochloric acid is normally present in the human stomach during the process of digestion in larger proportions than that added to milk in this process of cheese making. Further, 95 per cent of the added acid passes out of the cheese with the whey during the process of manufacture. On this account no objection can be made on sanitary grounds to the use of this acid in the manner and for the purposes described.

Among different lots of cheese, part of which was made with hydrochloric acid and part with calcium chlorid added to portions of the same milk after pasteurization, those made with acid were found to be more uniform in moisture content and superior both in flavor and texture to those made with calcium chlorid. The losses of fat in the whey are reduced by the use of the acid. Pasteurization and acidulation of milk for cheese making appear to be complementary processes. Used together they furnish a means for bringing milk daily into uniform condition both as to acidity and bacterial content for cheese-making purposes.

The acidulation of milk with hydrochloric acid after pasteurization is accomplished without difficulty or danger of curdling by running a small stream of the acid, of normal concentration, into the cooled milk as it flows from the continuous pasteurizer into the cheese vat. One pound of normal-strength acid is sufficient to raise 100 pounds of milk from 0.16 per cent to 0.25 per cent acidity (calculated as per cent of lactic acid). The amount of acid needed each day to bring the milk up to 0.25 per cent acidity is read from a table or calculated from the weight of the milk and its acidity, determined by the use of Manns's acid test (titration with tenth-normal sodium hydrate and phenolphthalein). The preparation of standard-strength acid in carboy lots for this work and the acidulation of milk present no great difficulty to anyone who is able to handle Manns's acid test correctly.

After the milk is pasteurized and acidulated three-fourths per cent of first-class starter is added and the vat is heated to 85°. It is set with rennet, using 2 ounces of rennet per thousand pounds of milk, so that the milk begins to curdle in 7 minutes and is cut with three-eighth inch knives in 25 minutes. All portions of the

work after adding rennet are carried out in an unvarying routine manner, according to a fixed-time schedule every day. As soon as the rennet has been added the cheese maker is able to calculate the exact time of day when each of the succeeding operations should be performed, and the work of making the cheese is thus simplified and systematized. It is possible that the routine process here described may be varied somewhat with advantage at different factories. For example, some experienced cheese makers may prefer to mat the curds on the bottom of the vat instead of on racks or may find the use of the "curd gauge" unnecessary, and local conditions may be found in different factories making other adjustments of details desirable. However, the experience already had with the process indicates that the routine of daily operations found suitable at any factory can be practiced there throughout the season without variation.

It is the intention to give the new process a thorough trial in different cheese factories in various localities to test its applicability to different milk supplies before recommending it for general use by cheese makers. These trials will show whether new difficulties may arise which were not encountered heretofore. Cheese makers are therefore advised to await the publication of results of further trials of the method by the writers before undertaking to use the new process at their factories.

The extra cost of making pasteurized-milk cheese is being studied with a view to finding out accurately what the net profit is in making this cheese compared with the regular process.

The new process should interest the farmer because of the increased yield and the avoidance of the usual losses in yield and quality of cheese due to defective milk. It should interest the cheese maker because the process of making is systematized to such a degree that it is conducted upon a fixed-time schedule for all operations. It should interest the dealer because the cheese is more uniform in quality and there is less need for cold storage in curing. Finally, the cheese should interest the consumer, because it is more uniform in flavor than most of the cheese to be found on retail counters and because it is made from pasteurized milk and is therefore a more sanitary product than ordinary American cheese made from raw milk.

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